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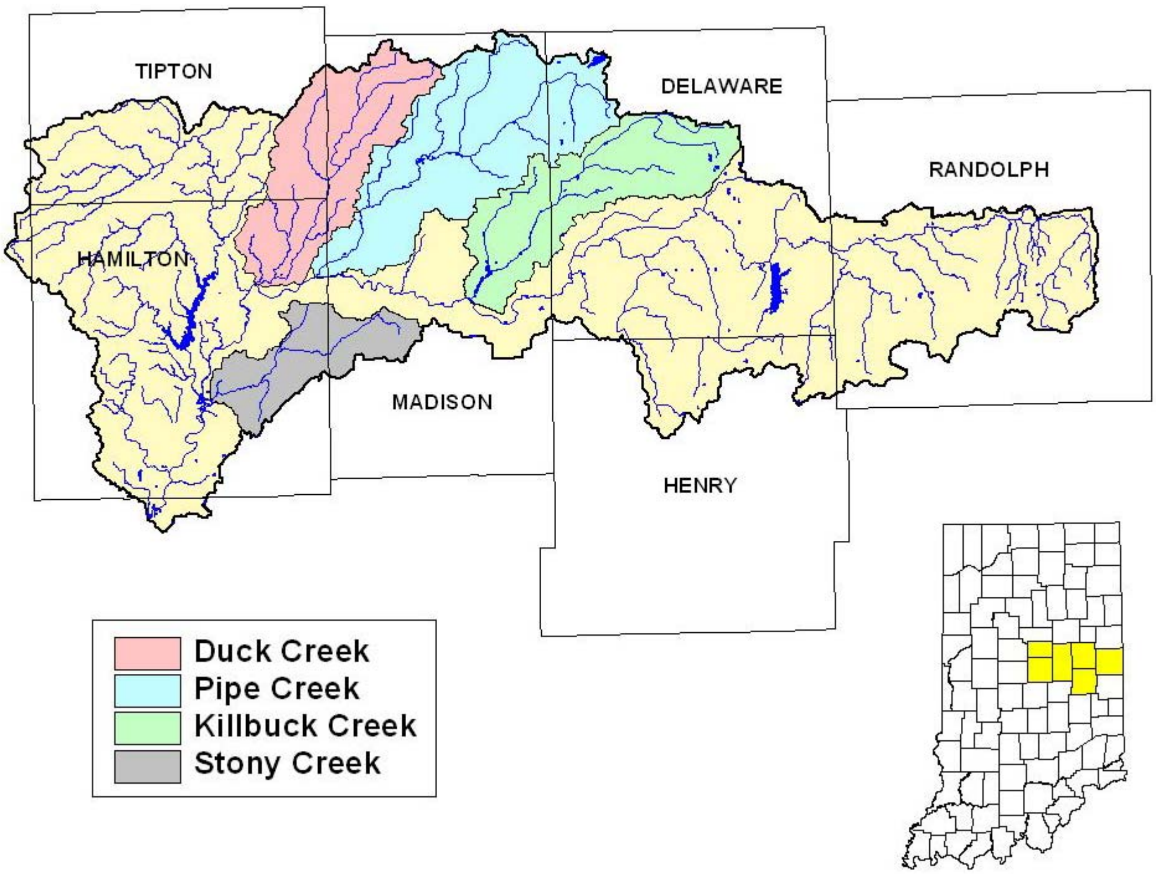
Duck Creek, Pipe Creek, Killbuck Creek, and Stony Creek TMDLs for *E. coli* Bacteria

TMDL Report

March 30, 2005



Prepared for: Prepared by:

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1.0 INTRODUCTION

1.1 BACKGROUND

The Duck Creek, Pipe Creek, Killbuck Creek, and Stony Creek watersheds in central Indiana all drain to the West Fork White River. Figure 1-1 shows the locations of these four watersheds within the upper portion of the larger West Fork White River basin, encompassed by Tipton, Madison, Delaware, and Hamilton counties. The watersheds range in size from approximately 57 square miles (Stony Creek) to approximately 153 square miles (Pipe Creek). Agriculture is a major activity within the area and row crops and pasture lands account for 80 to 95 percent of the land coverage in each of the four watersheds.

The State of Indiana's 2004 Section 303(d) list of impaired waters (IDEM, 2004) shows that the main stem water bodies in each of the four watersheds fail to support the state's recreation use. Table 1-1 shows the specific 303(d) listings for these waters and Figure 1-2 illustrates the spatial extents of the impairments. While the present analysis was conducted to address impairments in the main stems of the four watersheds, the methodology employed also establishes incremental load allocations for the contributing subwatersheds. As such, the reported load allocations could be used as TMDLs for these tributary waters.

Water quality data collected by the Indiana Department of Environmental Management (IDEM) in 1996 and 2001 showed that these waters failed to meet state water quality standards for Escherichia *coli* (*E. coli*). The presence of *E. coli* bacteria in surface waters typically indicates that human sewage and/or animal waste have been introduced into the waters. Potential sources of this bacterium include municipal wastewater treatment plant leaks, failing or illicitly connected septic systems, combined sewer overflows, agricultural and stormwater runoff that carries manure applied as fertilizer, wildlife, and direct releases from livestock or domestic pets.

The U.S. Environmental Protection Agency (EPA) requires that states develop Total Maximum Daily Loads (TMDLs) for all receiving water impairments included on the States' 303(d) lists. A TMDL is the mass loading of a pollutant that a water body can assimilate from all contributing sources while still maintaining water quality standards and supporting its designated uses. The U.S. EPA has established a project to develop *E. coli* TMDLs for the four watersheds in this study. Goals of the project are to:

- Collect existing data, models, and other information necessary to characterize the Duck Creek, Pipe Creek, Killbuck Creek, and Stony Creek watersheds, with respect to the impairments listed in Table 1-1,
- Use IDEM approved guidance and policies in developing TMDLs for the four watersheds,
- Use an innovative and cost-effective approach to establish the *E. coli* loading reductions required to meet the receiving stream's designated uses,
- Identify potential management practices that can be implemented to realize the loading reductions,
- Maintain contact with public stakeholders to ensure that the most appropriate information available is utilized, and that key concerns are addressed, and
- Submit draft and final TMDL reports to the U.S. EPA for review and approval.

This report represents the results of the TMDL project for the four watersheds. Section 2 includes a detailed description of the four watersheds and a discussion of all geospatial data layers and point location data available to quantify the extents of the impairments. An inventory and assessment of available *E. coli* water quality information in the four watersheds is provided in Section 3. An assessment of the various *E. coli* source categories in the four watersheds is presented in Section 4. Section 5 describes the "incremental watershed load duration curve (LDC)" approach applied in this project to establish the linkage between the source categories and the receiving streams' water quality. The *E. coli* load allocations and percent reductions for each of the four watersheds are presented in Section 6. Section 7 provides the project rationale for the margin-of-safety component of the TMDLs and Section 8 discusses how seasonal variability was considered in establishing the TMDLs. The public participation component of the TMDL project is outlined in Section 9. Finally, Section 10 provides a discussion on implementation options associated with the recommended TMDL load reductions.

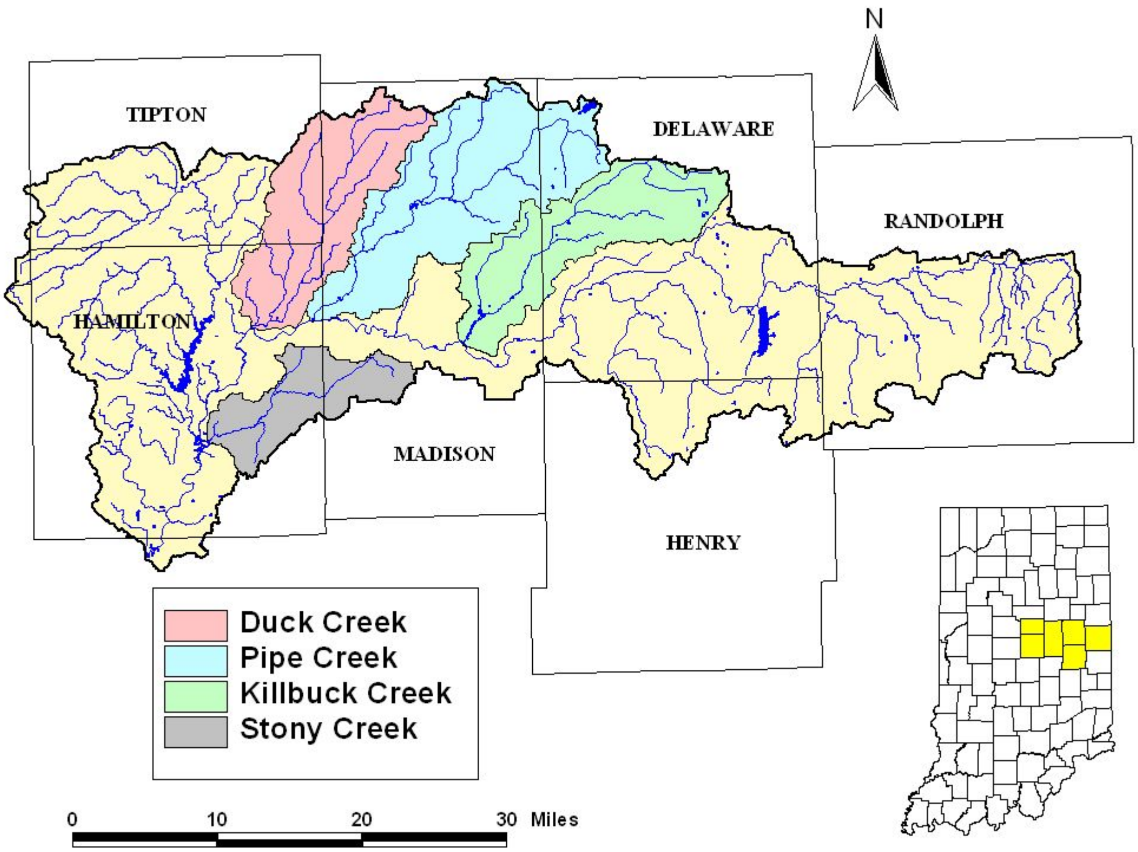

Figure 1-1. Study Area for the Duck Creek, Pipe Creek, Killbuck Creek, and Stony Creek watersheds

Table 1-1.IDEM 2004 Section 303(d) List of Water Quality Impairments in the Four Watersheds (IDEM, 2004)

Main Stem Impairments

303(d) #	Watershed	14 Digit HUC	County	Segment ID	Waterbody Name	Parameters of Concern
107	DUCK CREEK	5120201060020	MADISON CO	INW0162_T1028	DUCK CREEK - ELWOOD TO LTL DUCK CR	E. COLI
107	DUCK CREEK	5120201060030	MADISON CO	INW0163_T1029	DUCK CREEK - LTL DUCK CR TO POLYWOG CR	E. COLI
107	DUCK CREEK	5120201060040	HAMILTON CO	INW0164_T1030	DUCK CREEK	E. COLI
516	DUCK CREEK	5120201060060	HAMILTON CO	INW0166_00	DUCK CREEK	E. COLI
107	DUCK CREEK	5120201060060	HAMILTON CO	INW0166_T1031	DUCK CREEK	E. COLI
136	PIPE CREEK	5120201050020	MADISON CO	INW0152_00	PIPE CREEK	IMPAIRED BIOTIC COMMUNITIES, E. COLI
136	PIPE CREEK	5120201050020	MADISON CO	INW0152_T1020	PIPE CREEK	IMPAIRED BIOTIC COMMUNITIES, E. COLI
136	PIPE CREEK	5120201050030	MADISON CO	INW0153_T1021	PIPE CREEK	IMPAIRED BIOTIC COMMUNITIES, E. COLI
136	PIPE CREEK	5120201050040	MADISON CO	INW0154_T1022	PIPE CREEK	IMPAIRED BIOTIC COMMUNITIES, E. COLI
136	PIPE CREEK	5120201050060	MADISON CO	INW0156_T1023	PIPE CREEK	IMPAIRED BIOTIC COMMUNITIES, E. COLI
136	PIPE CREEK	5120201050070	MADISON CO	INW0157_T1024	PIPE CREEK	E. COLI
136	PIPE CREEK	5120201050080	MADISON CO	INW0158_T1025	PIPE CREEK	IMPAIRED BIOTIC COMMUNITIES, E. COLI
136	PIPE CREEK	5120201050090	HAMILTON CO	INW0159_00	PIPE CREEK - HAMILTON COUNTY	IMPAIRED BIOTIC COMMUNITIES, E. COLI
136	PIPE CREEK	5120201050090	MADISON CO	INW0159_T1026	PIPE CREEK - SWANFELT DT TO COUNTY LINE	IMPAIRED BIOTIC COMMUNITIES, E. COLI
520	KILLBUCK CREEK	5120201040010	DELAWARE CO	INW0141_00	KILLBUCK CREEK	IMPAIRED BIOTIC COMMUNITIES, E. COLI
520	KILLBUCK CREEK	5120201040050	DELAWARE CO	INW0145_00	KILLBUCK CREEK	E. COLI
125	KILLBUCK CREEK	5120201040050	MADISON CO	INW0145_T1016	KILLBUCK CREEK	IMPAIRED BIOTIC COMMUNITIES, E. COLI
125	KILLBUCK CREEK	5120201040070	MADISON CO	INW0147_T1017	KILLBUCK CREEK - TO MOUTH	IMPAIRED BIOTIC COMMUNITIES, E. COLI
512	STONY CREEK	5120201070040	MADISON CO	INW0174_00	STONEY CREEK-HEADWATERS	E. COLI
145	STONY CREEK	5120201070050	HAMILTON CO	INW0175_T1039	STONY CREEK	E. COLI, IMPAIRED BIOTIC COMMUNITIES
145	STONY CREEK	5120201070060	HAMILTON CO	INW0176_T1040	STONY CREEK	E. COLI, IMPAIRED BIOTIC COMMUNITIES
145	STONY CREEK	5120201070070	HAMILTON CO	INW0177_T1041	STONY CREEK	E. COLI, IMPAIRED BIOTIC COMMUNITIES

Tributary Impairments

303(d) #	Watershed	14 Digit HUC	County	Segment ID	Waterbody Name	Parameters of Concern
516	DUCK CREEK	5120201060010	MADISON CO	INW0161_00	DUCK CREEK-TODD DITCH	E. COLI
516	DUCK CREEK	5120201060020	MADISON CO	INW0162_00	LITTLE DUCK CREEK BASIN	E. COLI
516	DUCK CREEK	5120201060020	MADISON CO	INW0162_T1228	BIG DUCK CREEK	E. COLI
516	DUCK CREEK	5120201060030	MADISON CO	INW0163_00	POLYWOG CREEK	E. COLI
516	DUCK CREEK	5120201060060	HAMILTON CO	INW0166_T1227	LONG BRANCH	E. COLI
136	PIPE CREEK	5120201050010	DELAWARE CO	INW0151_00	PIPE CREEK-YEAGER FINLEY MENARD DITCH	IMPAIRED BIOTIC COMMUNITIES, E. COLI
520	KILLBUCK CREEK	5120201040020	DELAWARE CO	INW0142_00	KILLBUCK CREEK-THURSTON DITCH	IMPAIRED BIOTIC COMMUNITIES, E. COLI
520	KILLBUCK CREEK	5120201040040	DELAWARE CO	INW0144_00	KILLBUCK CREEK-PLEASANT RUN CREEK	IMPAIRED BIOTIC COMMUNITIES, E. COLI
520	KILLBUCK CREEK	5120201040030	DELAWARE CO	INW0143_00	JAKES CREEK-EAGLE BRANCH	E. COLI
520	KILLBUCK CREEK	5120201040060	MADISON CO	INW0146_00	LITTLE KILLBUCK CREEK-NELSON BROOK	E. COLI
512	STONY CREEK	5120201070050	HAMILTON CO	INW0175_00	STONEY CREEK - WILLIAM LOCK DITCH TRIBUTARIES	E. COLI
512	STONY CREEK	5120201070060	HAMILTON CO	INW0176_00	WILLIAM LEHR DITCH AND OTHER TRIBUTARIES	E. COLI
512	STONY CREEK	5120201070070	HAMILTON CO	INW0177_00	NORTH TRIB (NOBLESVILLE)	E. COLI

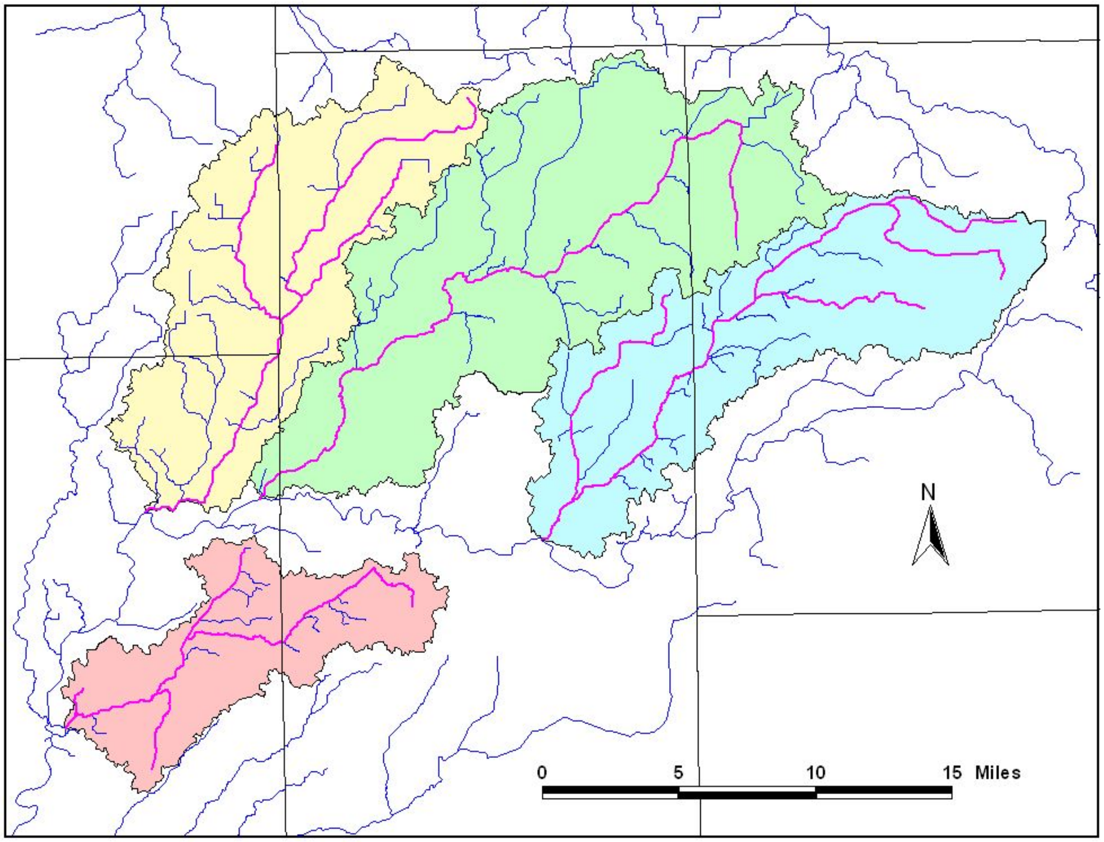

Figure 1-2. Spatial Extents of the *E. coli* Impairments in Each of the Four Watersheds

2.0 DESCRIPTION OF THE WATERSHEDS

The Duck Creek watershed encompasses approximately 105 square miles and includes portions of Tipton, Madison, and Hamilton counties (Figure 2-1). One incorporated urban center, the city of Elwood, is completely situated within the Duck Creek watershed boundary. The major tributaries within the Duck Creek watershed are Little Duck Creek, Polywog Creek, Bear Creek, and Lamberson Ditch.

The Pipe Creek watershed is the largest of the four watersheds (approximately 153 square miles) and spans across Hamilton, Madison, and Delaware counties (Figure 2-2). The Pipe Creek watershed completely encompasses the city of Alexandria, the towns of Frankton, Summitville, and Orestes, and partially includes the town of Gaston. Major tributaries within the Pipe Creek watershed are Mud Creek, Lilly Creek, and Alexandria Creek.

At approximately 104 square miles in area, the Killbuck Creek watershed is somewhat more urbanized than the Duck and Pipe Creek watersheds, and includes parts of Madison and Delaware counties (Figure 2-3). While the watershed does not completely surround any municipalities, two of the larger cities in the area, Muncie and Anderson, are partially contained within the watershed. The major tributaries in the Killbuck Creek watershed are Little Killbuck Creek, Mud Creek, Jake’s Creek, and Pleasant Run Creek.

The Stony Creek watershed is the smallest of the four watersheds (approximately 57 square miles) in this study and is approximately evenly split between Hamilton and Madison counties (Figure 2-4). The town of Lapel is completely situated within the Stony Creek watershed boundary and the larger city of Noblesville, which is quickly becoming a suburb of Indianapolis, is partly within the boundary of the watershed. The upper Stony watershed also includes a small portion of the city of Anderson. The major tributaries in the Stony Creek watershed are the William Lock Ditch and the William Lehr Ditch.

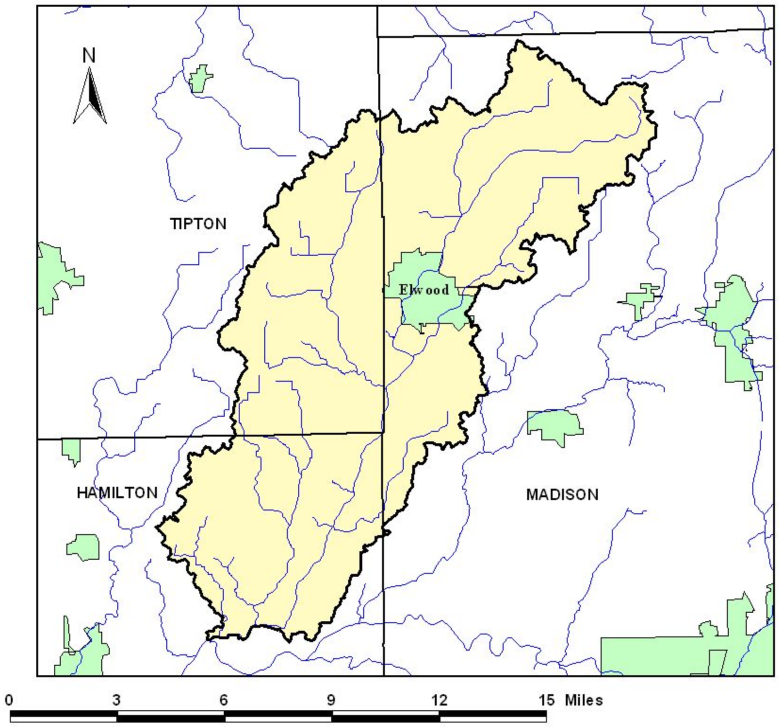

Figure 2-1. Spatial Extent of the Duck Creek Watershed, with Associated Communities.

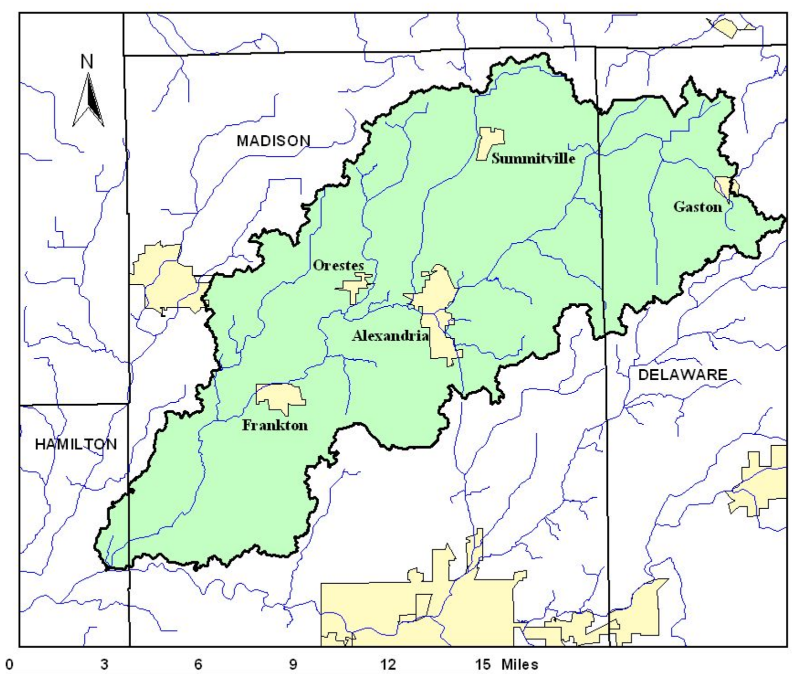

Figure 2-2. Spatial Extent of the Pipe Creek Watershed, with Associated Communities.

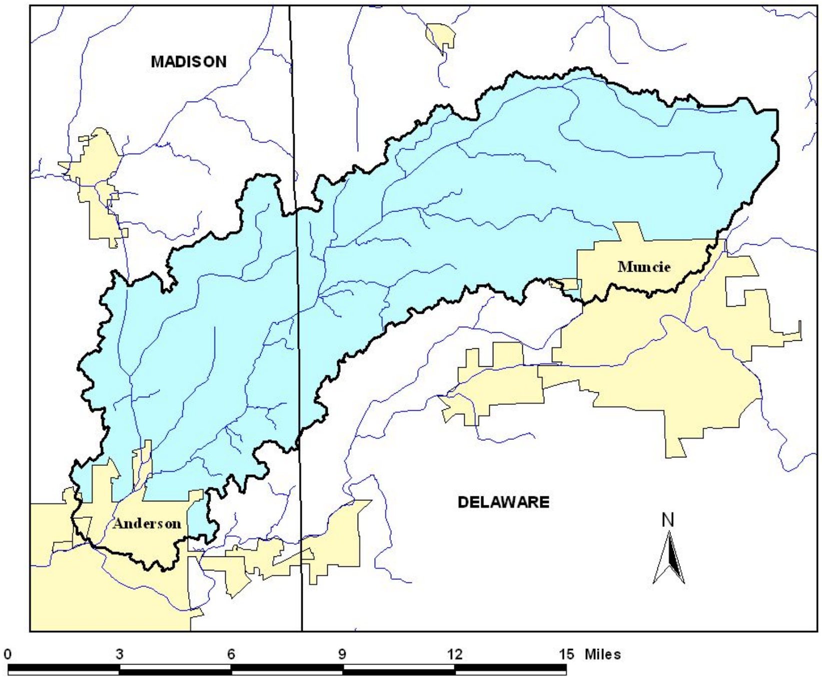

Figure 2-3. Spatial Extent of the Killbuck Creek Watershed, with Associated Communities.

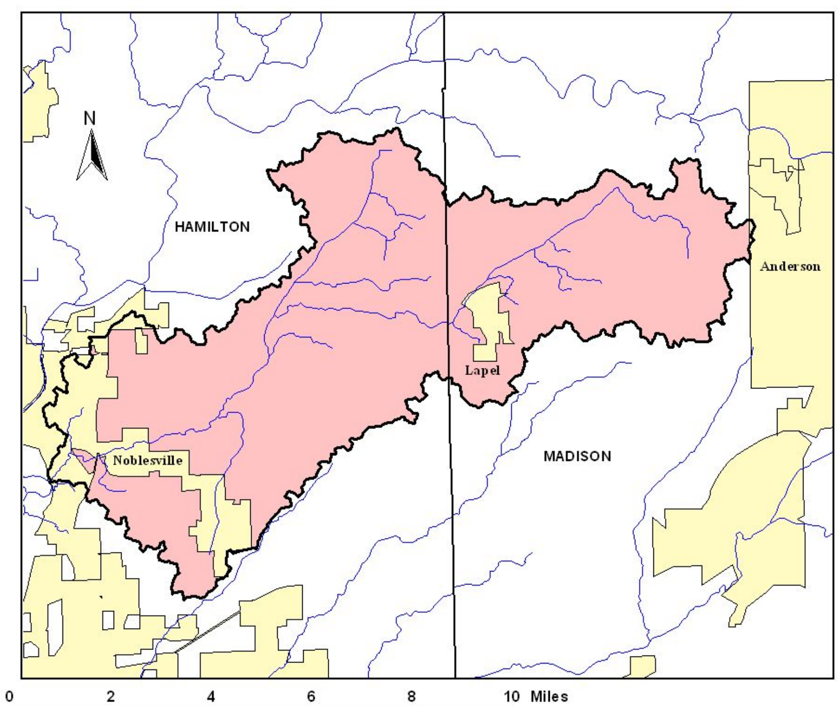

Figure 2-4. Spatial Extent of the Stony Creek Watershed, with Associated Communities.

2.1 POPULATION

Recent population changes within the four watersheds can be gauged by reviewing 1990 and 2000 census data for the ten municipalities that are completely or partially contained within the watersheds. Table 2-1 shows the changes in population that occurred in the ten municipalities during that time period. With the exceptions of Orestes and Muncie, all of the municipalities experienced growth over the ten years. Of particular note is the 62% growth that occurred in the city of Noblesville during that period. That growth is consistent with the rate for the rest of Hamilton County, which is one of the fastest growing counties in the country.

City	County	1990 Population	2000 Population	% Change
Alexandria	Madison	5,709	6,260	9.7%
Anderson	Madison	59,459	59,734	0.5%
Elwood	Madison	9,494	9,737	2.6%
Frankton	Madison	1,736	1,905	9.7%
Gaston	Delaware	979	1,010	3.2%
Lapel	Madison	1,742	1,855	6.5%
Muncie	Delaware	71,035	67,430	-5.1%
Noblesville	Hamilton	17,655	28,590	61.9%
Orestes	Madison	458	334	-27.1%
Summitville	Madison	1,010	1,090	7.9%

Table 2-1. Comparison of 1990 and 2000 Census Population Data for 10 Communities within the Four Watersheds (US Census Bureau, 2000)

2.2 TOPOGRAPHY

Multiple sources of elevation data were considered for use in this project. Ultimately, the Shuttle Radar Topography Mission dataset or SRTM (NASA, 2002) was selected for use in delineating the watersheds. This data was acquired from the USGS National Map Seamless Data Distribution System (*http://seamless.usgs.gov*) and is provided as unprojected grid data in decimal degrees and referenced to the World Geodetic System of 1984 (WGS84) horizontal datum. Elevation values are provided in meters. The SRTM dataset was acquired at a scale of one elevation value for each arc-second of latitude and longitude. For central Indiana, this corresponds to one elevation value for every 23.6 meters of latitudinal distance and one value for every 30.9 meters of longitudinal distance.

The SRTM was projected to the UTM-NAD27 map projection with a grid cell size of 30 meters. The resultant grid was then converted to vertical units of feet. Figure 2-5 shows the entire SRTM dataset for the study area encompassing the four watersheds.

Figure 2-6 shows the SRTM elevations for the Duck Creek watershed, as defined by the SRTM delineation. Elevations in the Duck Creek watershed range from 790 feet at the confluence with the West Fork White River to 936 feet in the headwaters. Average slope in the watershed (calculated as the average of slopes in all 30 meter x 30 meter grid cells) is 2.9 percent.

The Pipe Creek watershed SRTM elevations are shown in Figure 2-7. Elevations range between 795 feet at the confluence with the West Fork White River to 947 feet in the headwaters. Average slope in the Pipe Creek watershed is 3.4 percent.

The Killbuck Creek watershed SRTM elevation distributions are presented in Figure 2-8. The high point of the watershed, in the headwaters near Muncie is 979 feet and elevation at the outlet to the West Fork White River is 846 feet. The average slope in the Killbuck Creek watershed is 3.9 percent.

Figure 2-9 presents the Stony Creek watershed SRTM elevations. Elevations in this watershed range from 757 feet at the confluence with West Fork White River at Noblesville to 918 feet in the headwaters. Average slope in the Stony Creek watershed is 3.6 percent.

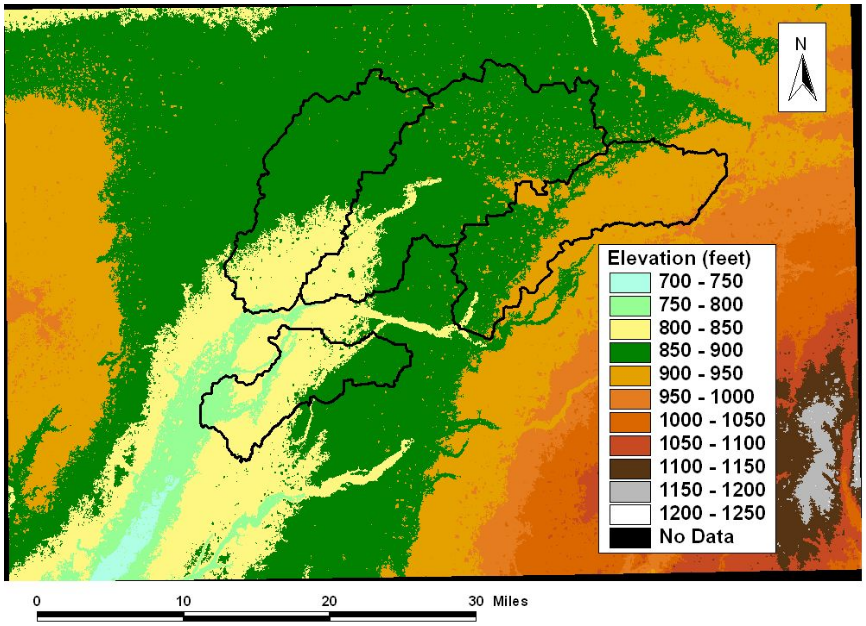

Figure 2-5. Shuttle Radar Topography Mission (SRTM) Elevations for the Duck, Pipe, Killbuck, and Stony Creek TMDL Study Area

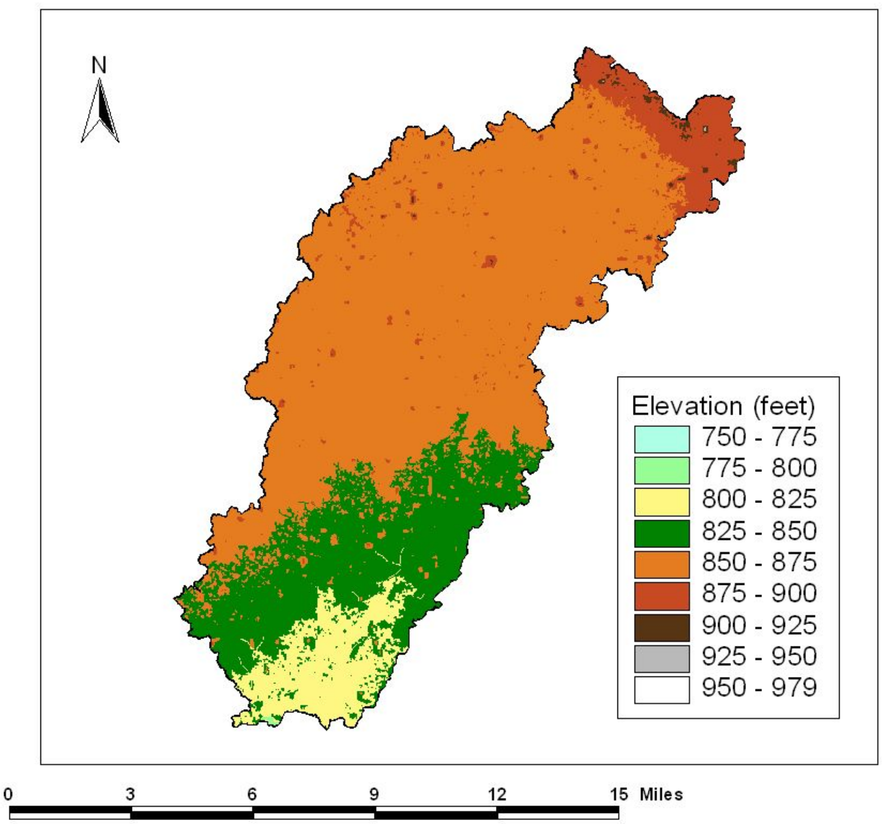

Figure 2-6. SRTM Elevations for the Duck Creek watershed

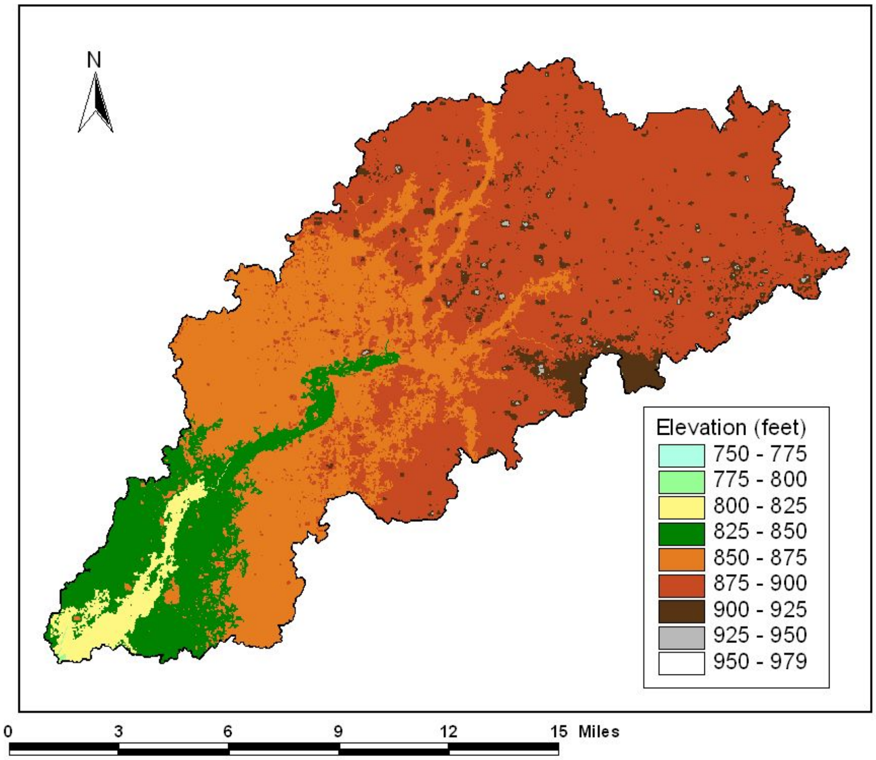

Figure 2-7. SRTM Elevations for the Pipe Creek watershed

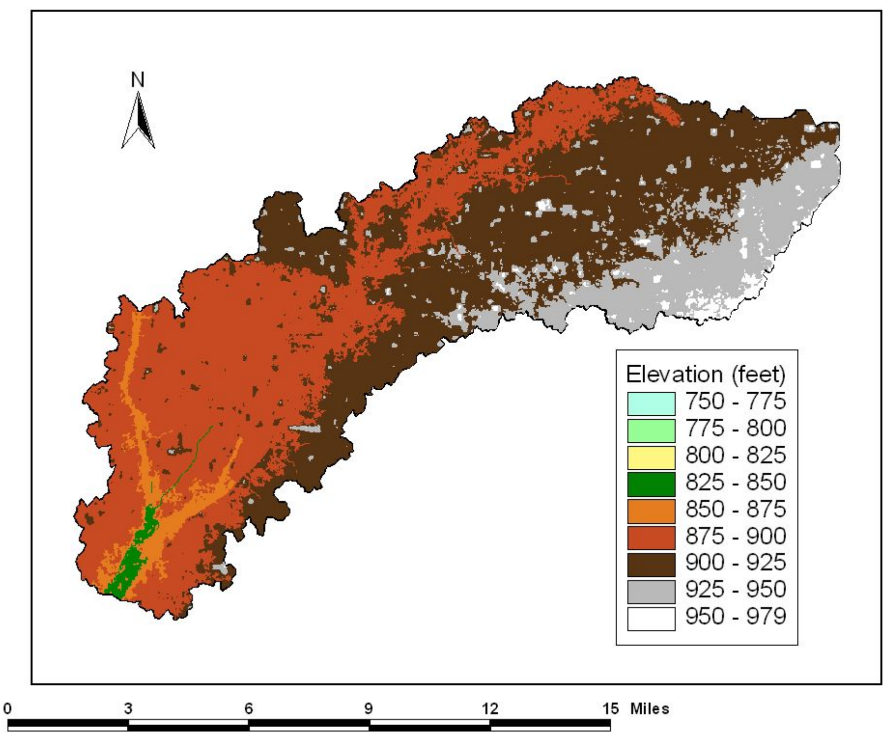

Figure 2-8. SRTM Elevations for the Killbuck Creek watershed

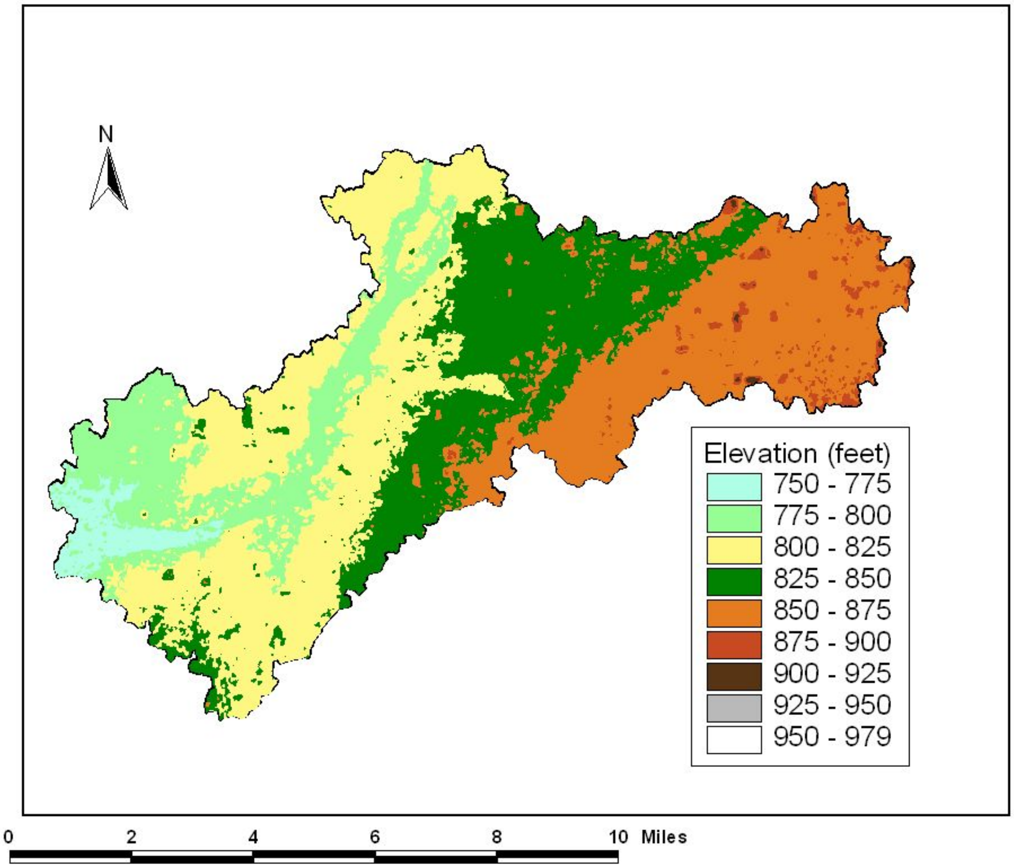

Figure 2-9. SRTM Elevations for the Stony Creek watershed

2.3 LAND USE

The National Land Cover Dataset, or NLCD (USGS, 1999) provides the source for the land use/land cover layer used for this project. The NLCD was acquired from the Indiana Geological Survey website. The NLCD was cooperatively produced by the USGS and the USEPA to maintain a consistent, land cover data layer for the United States, based on 30-meter Landsat thematic mapper (TM) data. The TM data used for creation of the NLCD was acquired by the Multi-Resolution Land Characterization (MRLC) Consortium, which includes the USGS, USEPA, the U.S. Forest Service (USFS), and the National Oceanic and Atmospheric Administration (NOAA). This Indiana data layer was updated in 1999 and nominally includes land cover classifications as observed in 1992. The NLCD is provided in grid format with one land use classification value for each 30 meter x 30 meter parcel of land, and is projected in an Albers Conical Equal Area projection referencing the NAD83 datum.

The NLCD grid was converted to a polygon shapefile, and then reprojected to the UTM NAD27 map projection. Figures 2-10 through 2-13 show the resultant land use coverages, as clipped to the SRTM-delineated boundaries for each watershed. As can be seen from the figures, each watershed is dominated by agricultural row crop classifications. Table 2- 2 shows the percentile breakdown of NLCD categories in each of the four watersheds. Row crops account for between 66% (Killbuck Creek watershed) and 85% (Duck Creek watershed) of the land uses in the study area. The row crops and pasture land acreage, when considered together, make up over 90% of the land coverage in three of the four watersheds (Duck, Pipe, and Stony Creek). The sum of row crop and pasture land acreage in the Killbuck Creek watershed is approximately 81%.

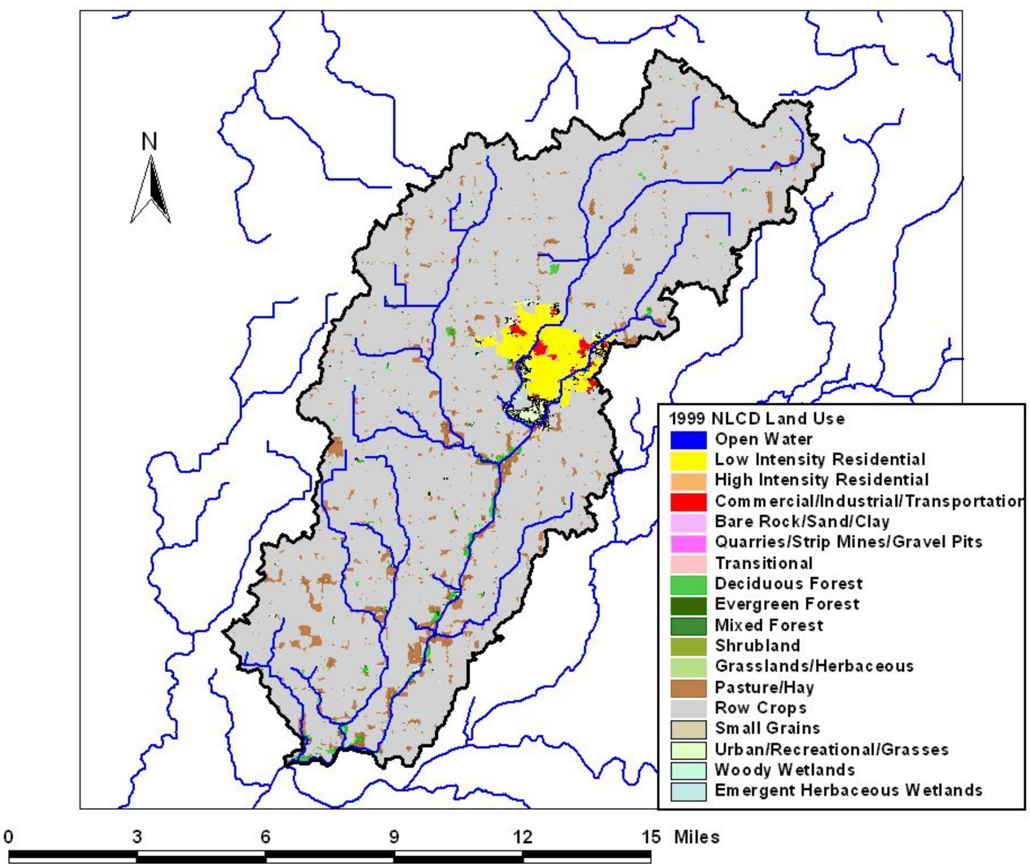

Figure 2-10. NLCD Land Cover Classifications for the Duck Creek Watershed

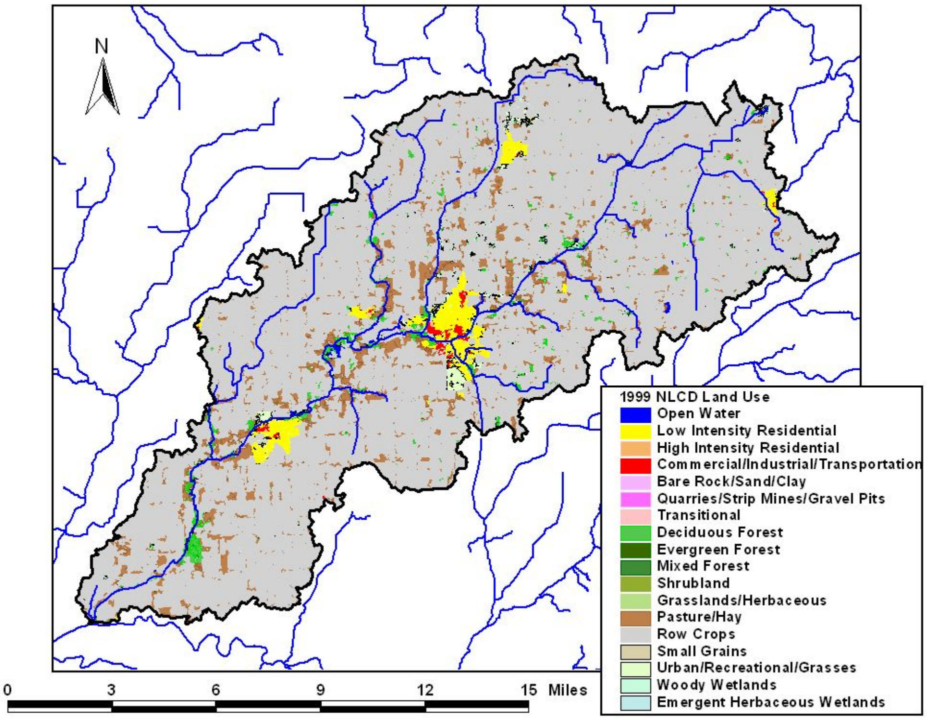

Figure 2-11. NLCD Land Cover Classifications for the Pipe Creek Watershed

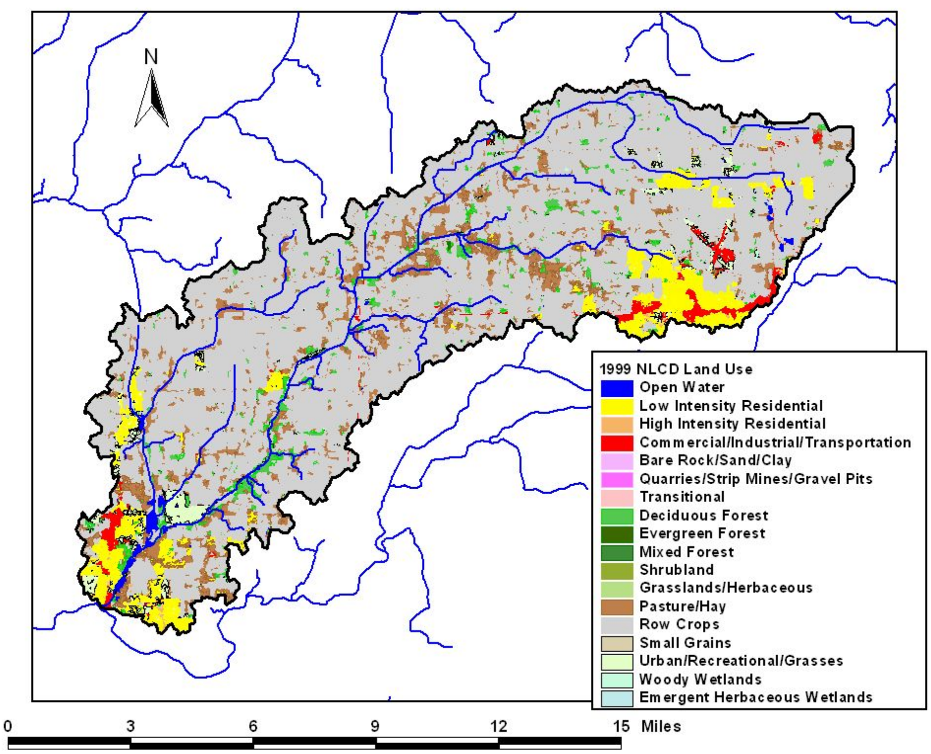

Figure 2-12. NLCD Land Cover Classifications for the Killbuck Creek Watershed

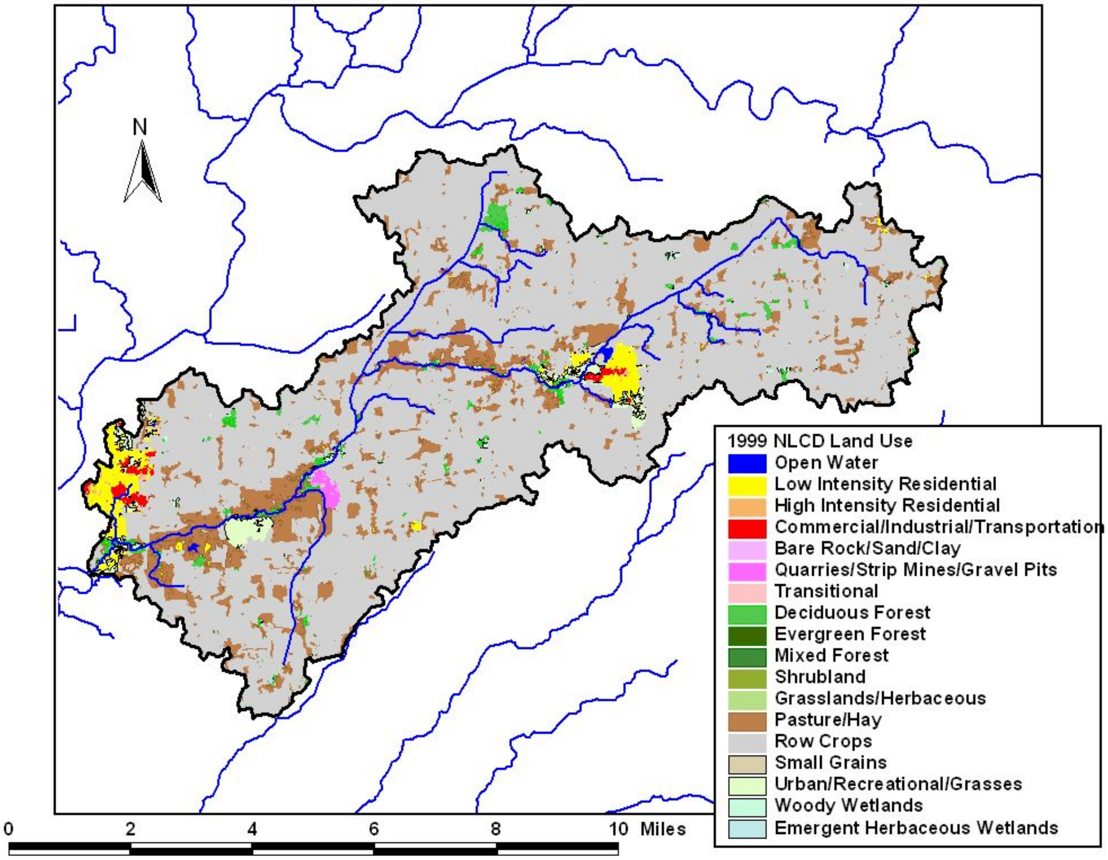

Figure 2-13. NLCD Land Cover Classifications for the Stony Creek Watershed

Table 2-2. Land Use Distributions in the Duck Creek, Pipe Creek, Killbuck Creek, and Stony Creek Watersheds (NLCD)

NLCD Land Use Category (MRLC Classifications)	Duck Creek Area (acres)	Duck Creek Percent	Pipe Creek Area (acres)	Pipe Creek Percent	Killbuck Creek Area (acres)	Killbuck Creek Percent	Stony Creek Area (acres)	Stony Creek Percent
Open Water	8	0.01%	192	0.2%	349	0.5%	47	0.1%
Low Intensity Residential	1,715	2.6%	2,254	2.3%	4,490	6.7%	855	2.4%
High Intensity Residential	138	0.2%	131	0.1%	343	0.5%	103	0.3%
Commercial/Industrial/Transportation	287	0.4%	432	0.4%	1,263	1.9%	234	0.7%
Quarries/Strip Mines/Gravel Pits	0.0	0.0%	0.0	0.0%	0.0	0.0%	109	0.3%
Deciduous Forest	1,045	1.6%	2,829	2.8%	3,404	5.1%	931	2.6%
Evergreen Forest	0.7	0.001%	3	0.003%	17	0.03%	0.7	0.002%
Mixed Forest	0.7	0.001%	1	0.001%	2	0.003%	0.4	0.001%
Pasture/Hay	5,499	8.4%	11,679	11.7%	9,564	14.4%	6,242	17.5%
Row Crops	55,399	84.7%	79,413	79.8%	44,506	66.8%	26,092	73.3%
Urban/Recreational/Grasses	623	1.0%	1,051	1.1%	2,140	3.2%	666	1.9%
Woody Wetlands	718	1.1%	1,456	1.5%	483	0.7%	296	0.8%
Emergent Herbaceous Wetlands	8	0.01%	62	0.1%	45	0.1%	7	0.02%
Totals	65,442	100.0%	99,503	100.0%	66,605	100.0%	35,583	100.0%

2.4 SOILS

Soils data are commonly available from the US Department of Agriculture – Natural Resources Conservation Service (USDA-NRCS) in two formats: the 1:250,000-scale State Soil Geographic (STATSGO) database, and the 1:24,000-scale Soil Survey Geographic (SSURGO) database. While the SSURGO database would be the preferred soils data layer for this project, the SSURGO data layer for Madison County is not yet available for public distribution. Unfortunately, Madison County includes significant portions of all four watersheds in this study. For this reason, the STATSGO database (USDA-NRCS, 2002) was selected to characterize the soils distribution in each of the four watersheds. The STATSGO layer for Indiana was acquired from the IGS website and reprojected to UTM – NAD27.

The attributes of interest in the STATSGO soils layer are the hydrologic soil group and the drainage classification. From the hydrologic soil group perspective, the soils in each of the four watersheds are quite similar, with the upper watershed areas having class C soils with slow infiltration rates. In the lower watershed riparian zones, soils generally become better drained with the moderate infiltration rates associated with hydrologic soil group B. The Duck Creek watershed also has some upper watershed areas classified as class B/D, which are typically poorly drained soils that can be managed to improve infiltration to moderate rates. Figures 2-14 through 2-17 show the STATSGO Hydrologic Soil Groups for all four watersheds.

Drainage Classification is the other STATSGO attribute of interest for this project. Drainage classification will be used along with the NLCD row crop category to identify probable tile drained parcels. These two attributes are almost redundant in the information that they convey. However, there are some parcels that are classified as having soil group C but are also moderately well drained (see Pipe and Killbuck Creeks). Figures 2-18 through 2-21 show the STATSGO Drainage Classifications for all four watersheds.

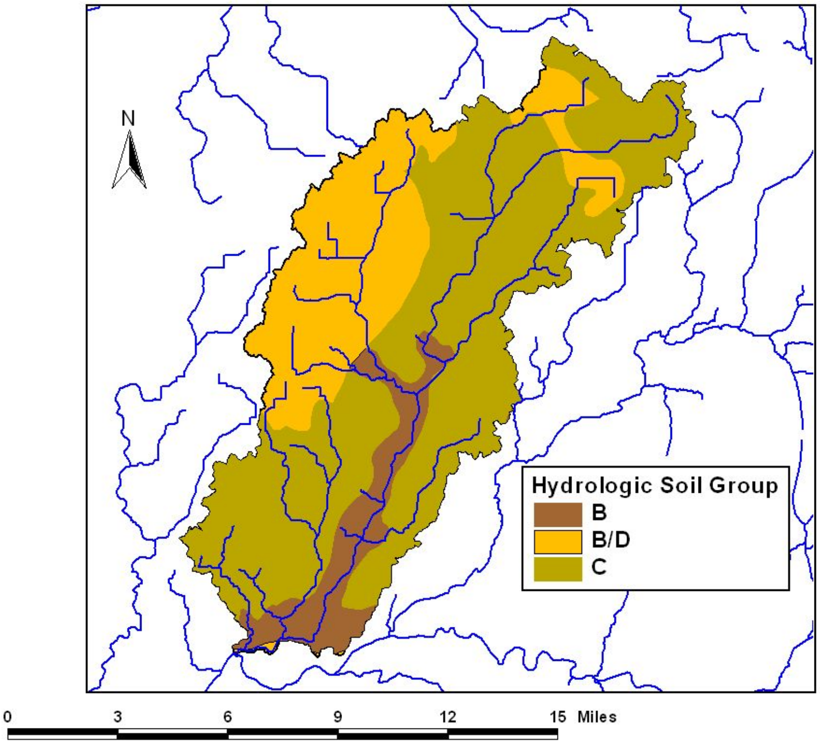

Figure 2-14. STATSGO Hydrologic Soil Group Categories for the Duck Creek Watershed

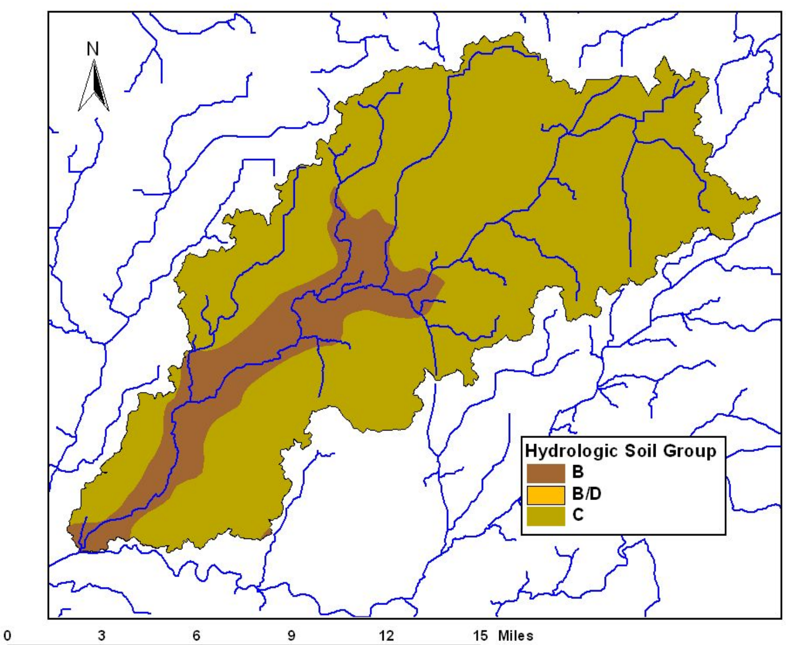

Figure 2-15. STATSGO Hydrologic Soil Group Categories for the Pipe Creek Watershed

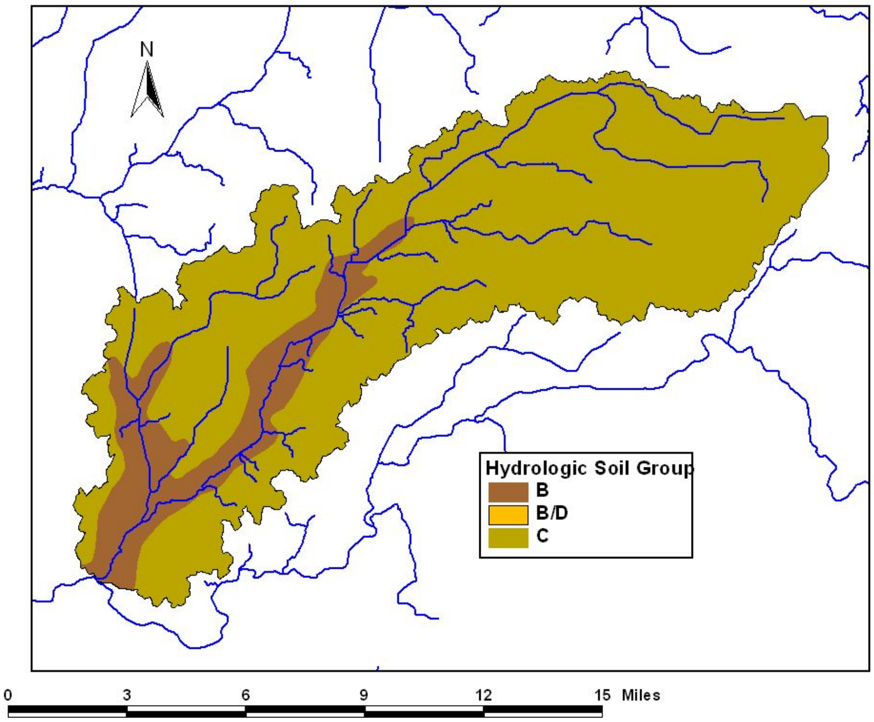

Figure 2-16. STATSGO Hydrologic Soil Group Categories for the Killbuck Creek Watershed

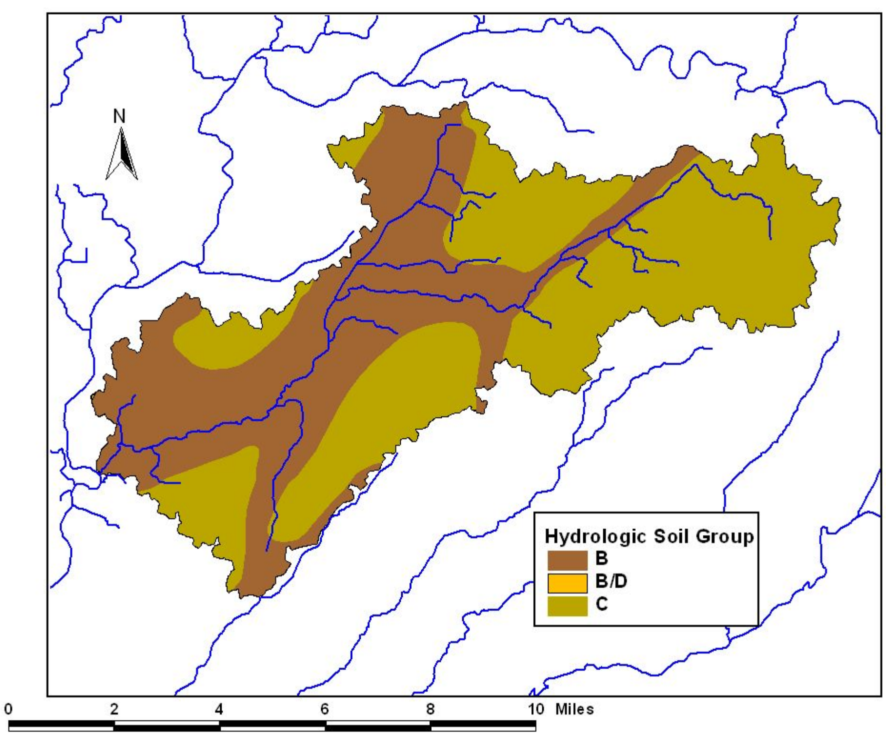

Figure 2-17. STATSGO Hydrologic Soil Group Categories for the Stony Creek Watershed

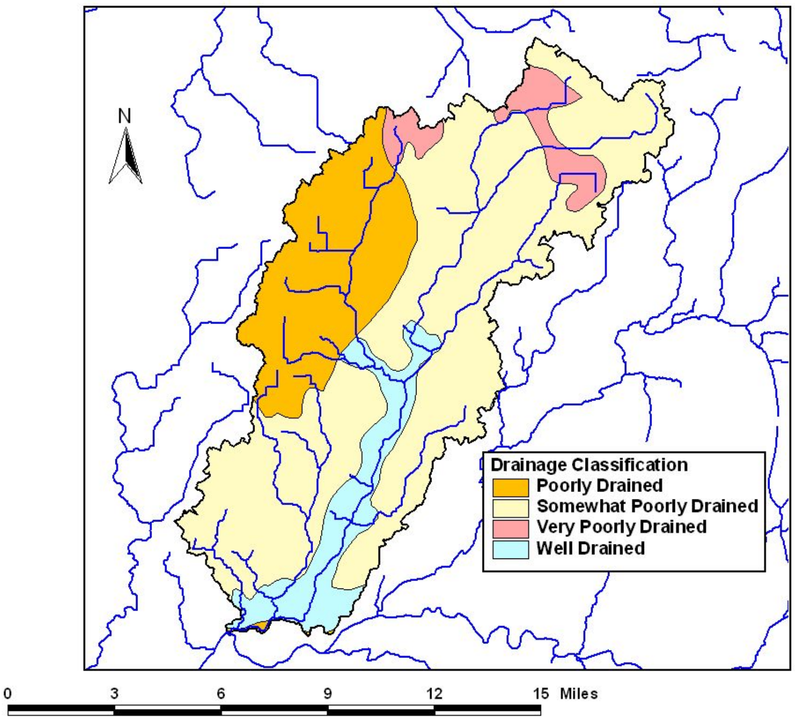

Figure 2-18. STATSGO Drainage Classification Categories for the Duck Creek Watershed

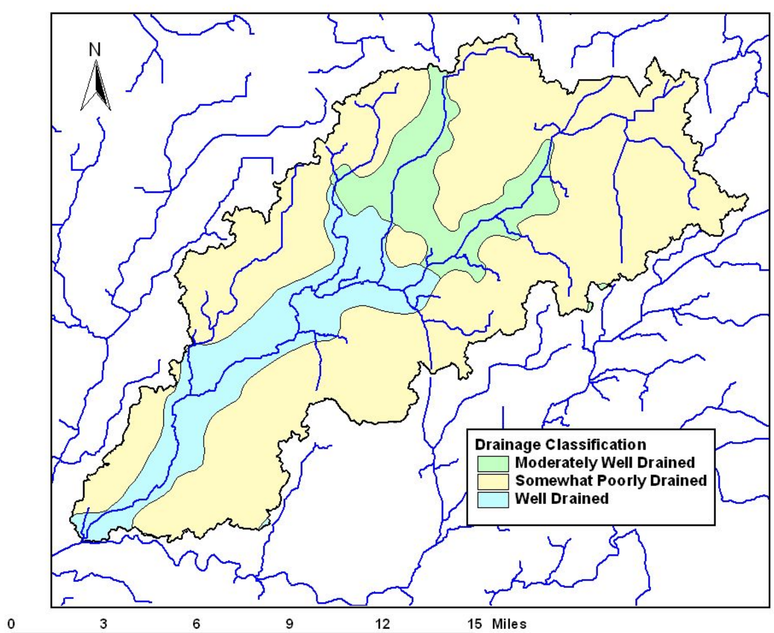

Figure 2-19. STATSGO Drainage Classification Categories for the Pipe Creek Watershed

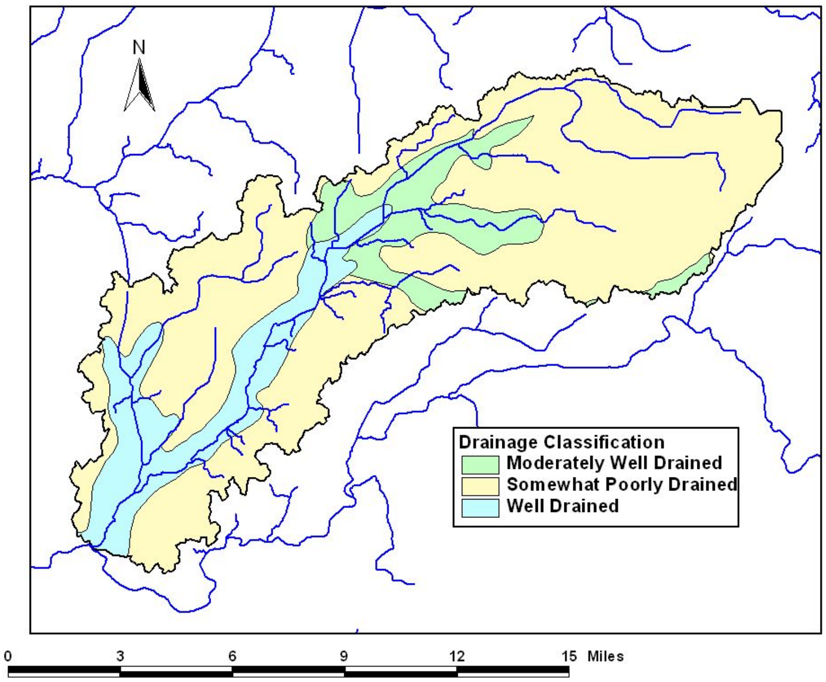

Figure 2-20. STATSGO Drainage Classification Categories for the Killbuck Creek Watershed

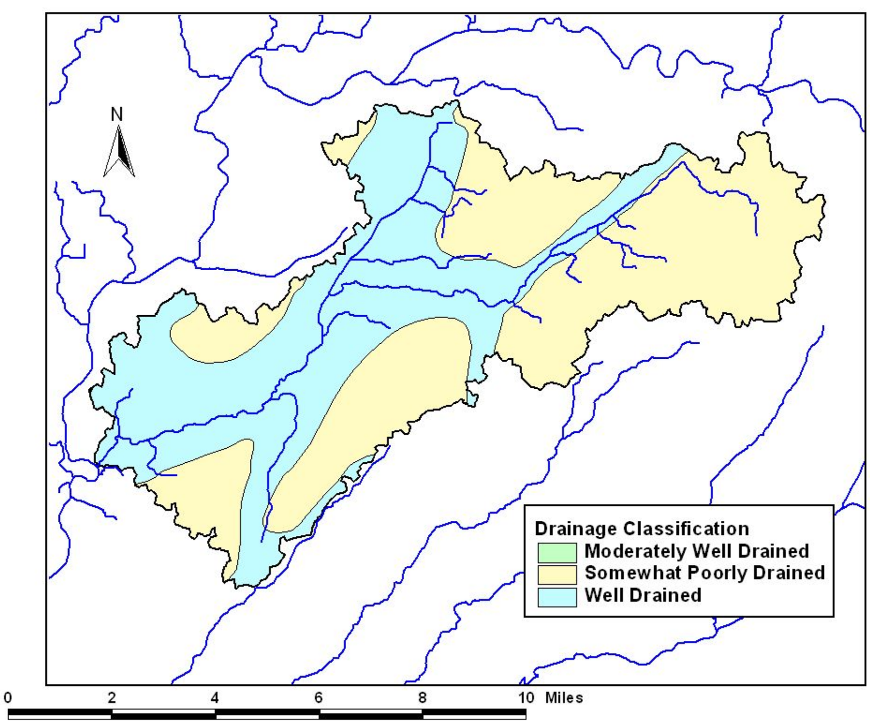

Figure 2-21. STATSGO Drainage Classification Categories for the Stony Creek Watershed

2.5 ROW CROP PATTERNS

Annual crop distributions are available from the U.S. Department of Agriculture National Agricultural Statistics Service (USDA-NASS, 2003). For this project, Grid files of the row crop distributions for the years 2000 – 2002 were acquired from the Purdue University Agricultural and Biological Engineering Department. This data was valuable in identifying specific crop locations where tile drainage is also probable due to soil characteristics. The row crop distributions are projected in the UTM – NAD83 map projection. Non-row crop land coverage (e.g. urban, open water, wetland, forest land) are also noted in the layers. Figures 2-22 through 2-25 show the 2001 row crop distributions for all four watersheds. These figures show that corn and soybeans were the predominant crops in all four watersheds during 2001.

Implementation of tile drainage is a common practice in central Indiana where soils would otherwise be poorly drained. The effects of tile drainage on rainfall runoff may be important in establishing the transport of *E. coli* bacteria from row crop fields to receiving waters. Discussions with Purdue Extension personnel (Frankenburger, 2004) have indicated that no explicit geospatial data layer of tile drained row crop fields currently exists. However, common practice in identifying those locations is to intersect the NLCD row crop parcels with soils data layer parcels that are identified as "poorly drained", "somewhat poorly drained", or "very poorly drained". Implementation of tile drainage actually mitigates the first flush of rainfall runoff from the row crop fields, as the collected precipitation volume is temporarily stored in the shallow soils of the fields. The stored volume is then gradually released as it percolates through the soils to the drains. Common observations of tile drained runoff have shown that the practice tends to increase nutrient loading to the receiving waters, as the percolating waters carry nutrients from the subsurface to the drains. However, similar observations have not been made with respect to *E. coli* bacteria.

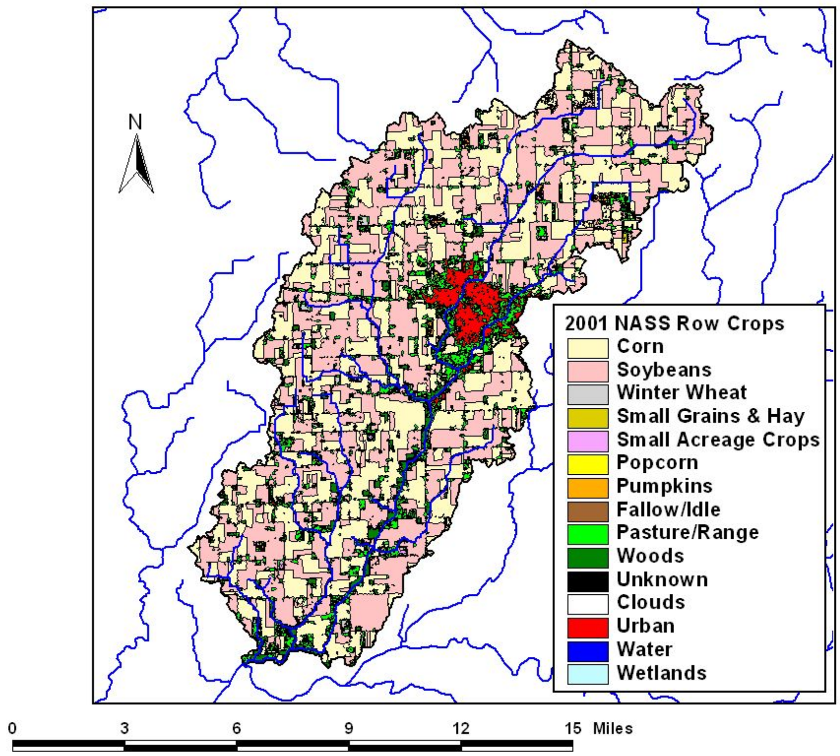

Figure 2-22. 2001 NASS Row Crop Distributions for the Duck Creek Watershed

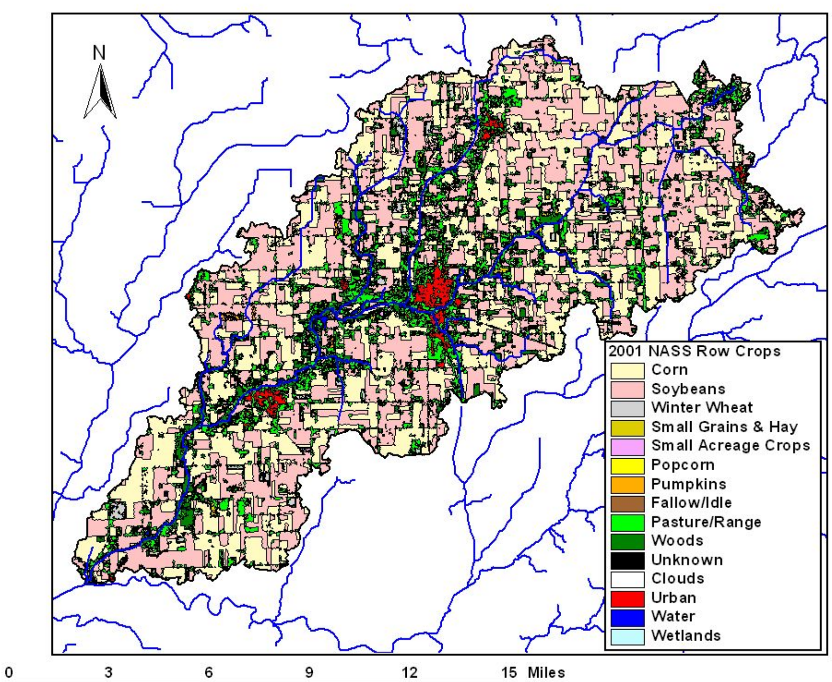

Figure 2-23.2001 NASS Row Crop Distributions for the Pipe Creek Watershed

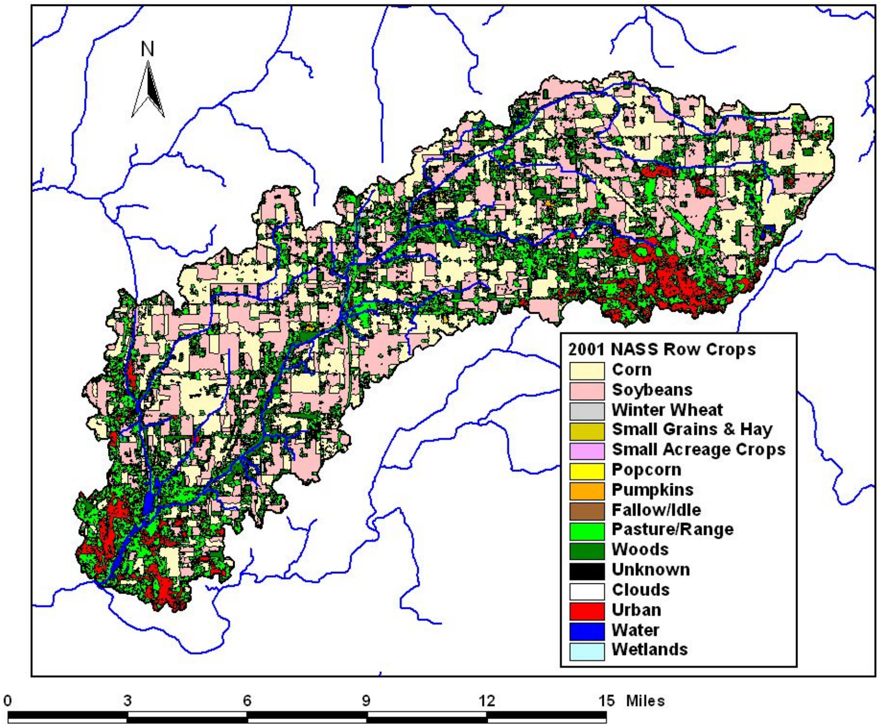

Figure 2-24. 2001 NASS Row Crop Distributions for the Killbuck Creek Watershed

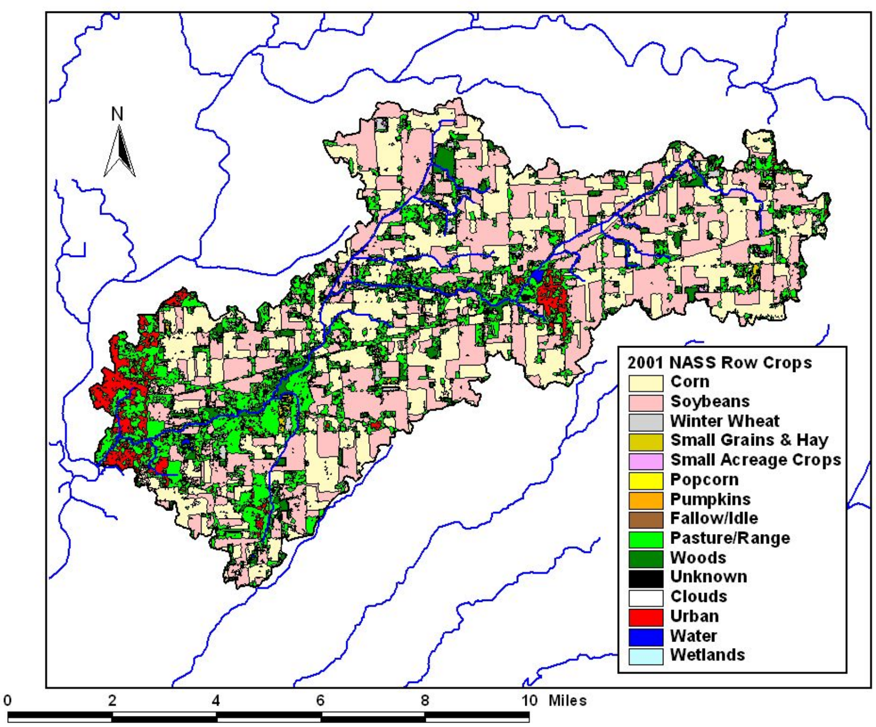

Figure 2-25.2001 NASS Row Crop Distributions for the Stony Creek Watershed

2.6 PRECIPITATION

Three National Climatic Data Center (NCDC) gages are located near the study watersheds and provide temperature and precipitation data (NCDC, 2004). These are Farmland 5 (IN2825), the gage at Anderson STP (IN0177) and Tipton 5 SW (IN8784). Additional precipitation data have been collected in the Killbuck Creek watershed during 2002-2004 as a component of the White Fork Watershed Project (Delaware County SWCD, 2002-2004).

The majority of IDEM's water quality samples were collected during the summer of 2001, so monthly precipitation data for 2001 was examined for each of the three stations. Figure 2-26 presents a comparison of this data for all three stations.

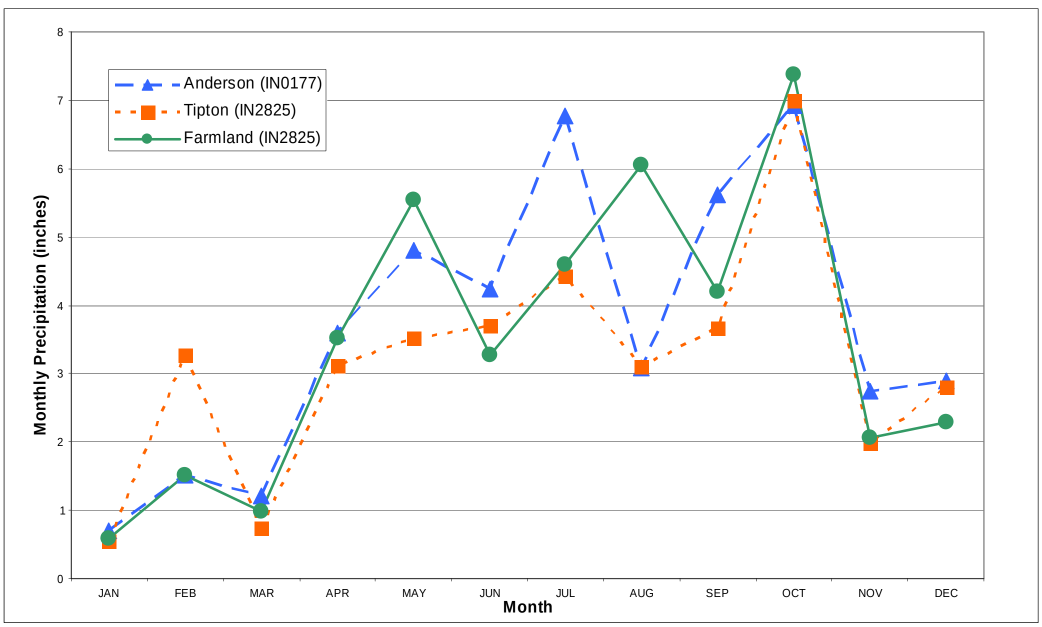

Figure 2-26. Monthly Precipitation in 2001 at Three NCDC Gages near Subject Watersheds

Precipitation data collected during the water quality assessment period show that from 1994- early 2004, the average annual precipitation in the study watersheds was 38.3 inches with a maximum annual precipitation of 50.7 inches and a minimum of 29.1 inches. Figure 2-27 shows the annual precipitation at these stations from the beginning of the assessment period to the present.

Additionally, daily precipitation values for the nearest station, Muncie Municipal Airport, were obtained for the water quality assessment period from April – July 2001. These values are presented in Figure 2-28 (NCDC, 2005).

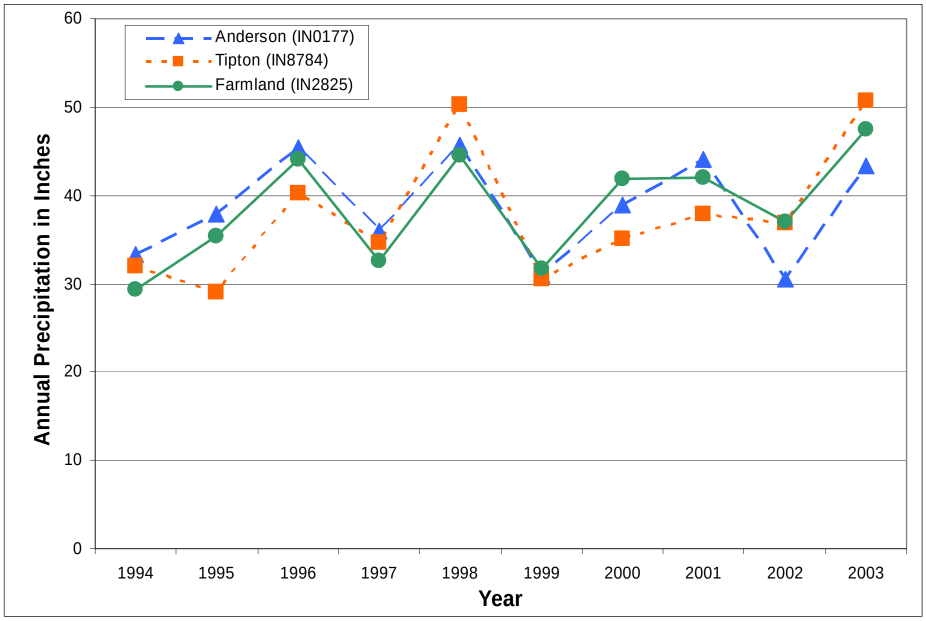

Figure 2-27. Annual Precipitation at Three NCDC Gages near Subject Watersheds

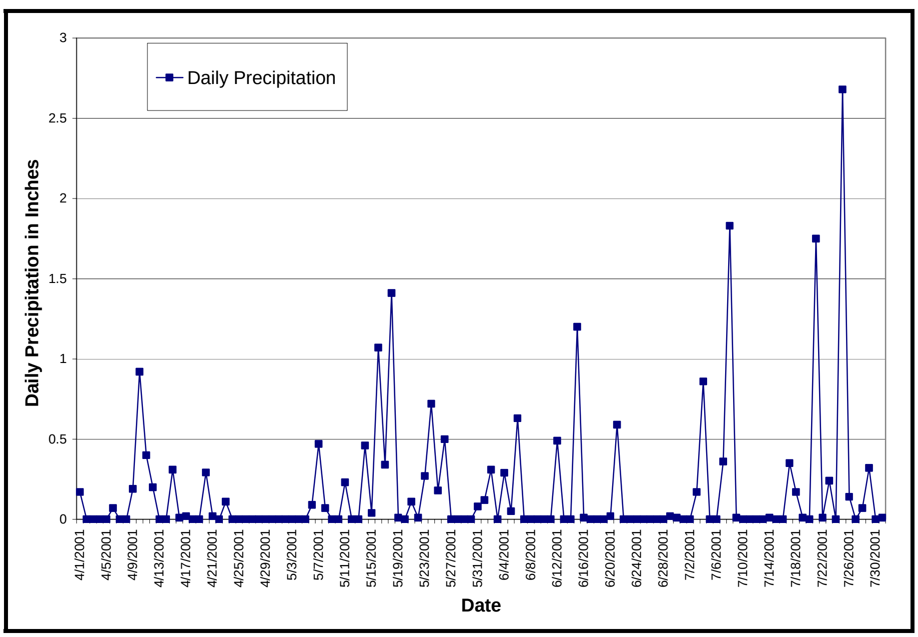

Figure 2-28. Daily Precipitation Values at Muncie Municipal Airport during the Water Quality Assessment Period of April – July 2001.

2.7 HYDROGRAPHY

The USGS 1:100,000 scale National Hydrography Dataset, or NHD (USGS, 2002) was selected to represent the stream network in the four watersheds. The NHD was constructed as a cooperative effort between the USGS and the EPA to combine the respective attributes of the earlier USGS Digital Line Graph (DLG) layer and the EPA's River Reach File 3 (RF3). The NHD was acquired from the Indiana Geological Survey (IGS) website (*http://igs.indiana.edu*), reprojected to UTM – NAD27, and clipped to the extent of the SRTM-delineated watersheds. In order to facilitate accurate delineation of watershed boundaries in flat areas, it is imperative that upper watershed (i.e. first order) streams in the delineated and adjacent watersheds are included in the hydrography layer. Upon inspection of the NHD for the four watersheds, it was apparent that some of these upper watershed canals and ditches were not included. For those cases, the missing first order streams were manually extracted from digital raster graphic (DRG) quadrangle maps of the study area (USGS, 1996) and added into the hydrography layer. Figures 2-29 through 2-32 show the NHD data layers for each watershed. Upper watershed streams that were extracted from the DRG maps are also identified in the figures.

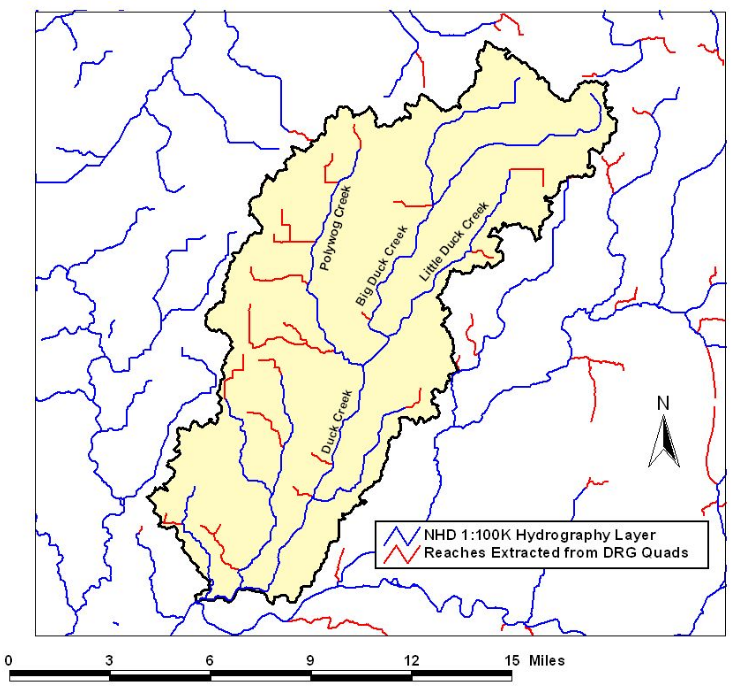

Figure 2-29. NHD Appended Hydrography for the Duck Creek Watershed

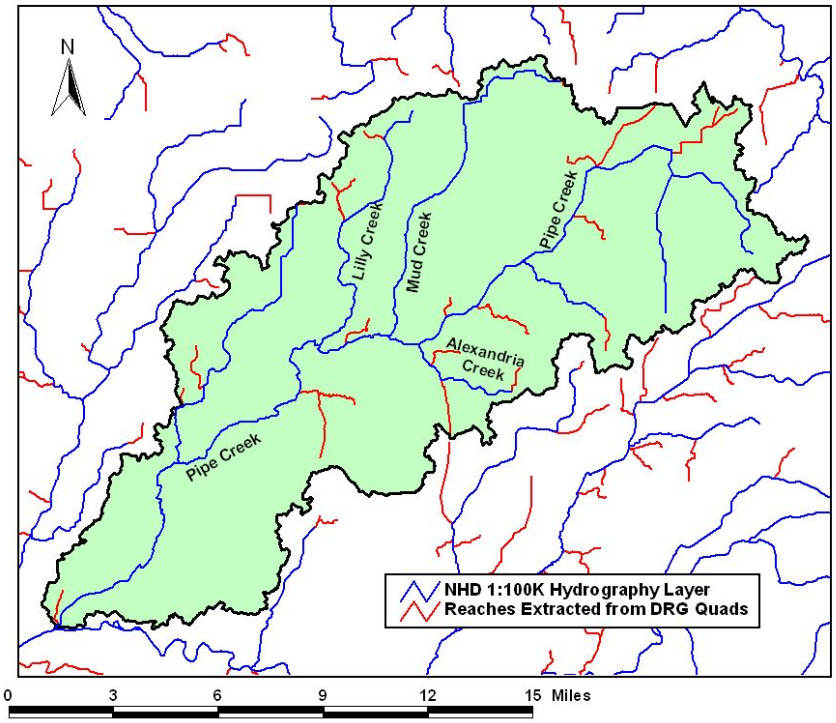

Figure 2-30. NHD Appended Hydrography for the Pipe Creek Watershed

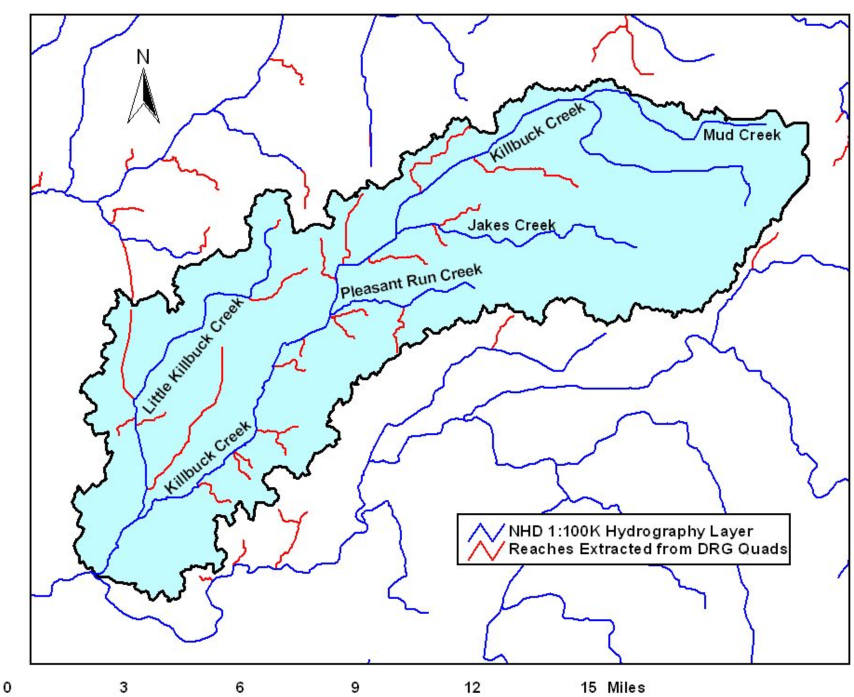

Figure 2-31. NHD Appended Hydrography for the Killbuck Creek Watershed

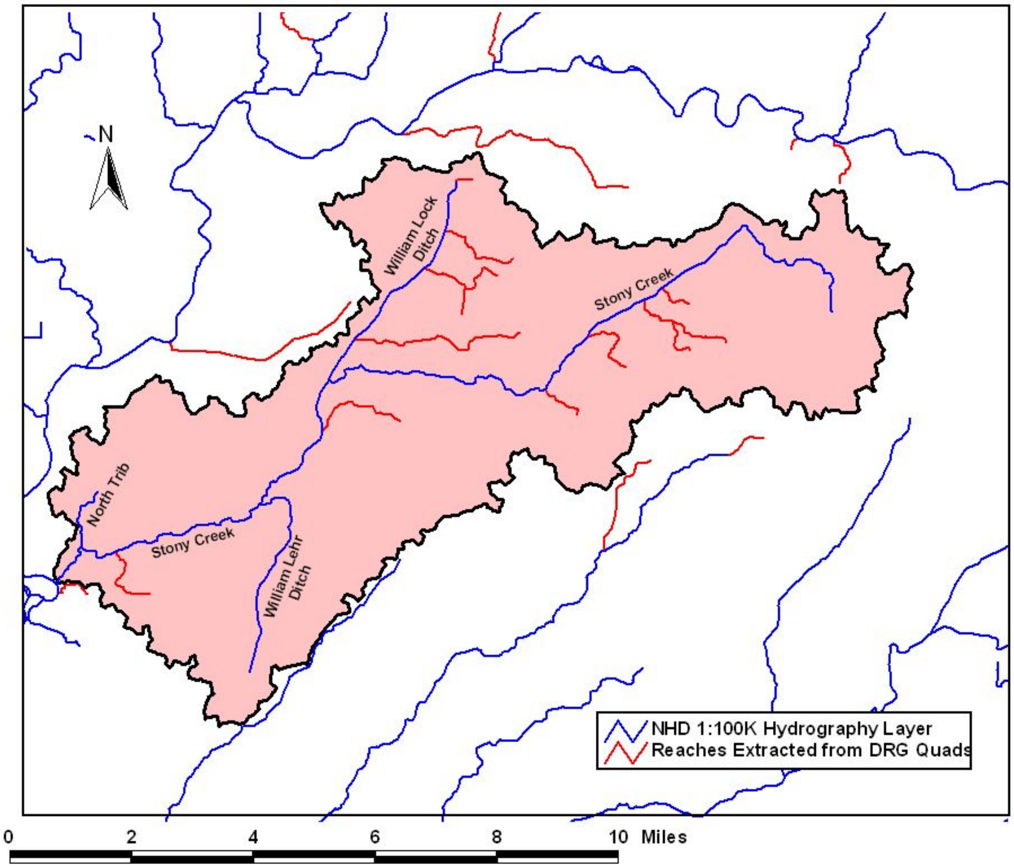

Figure 2-32. NHD Appended Hydrography for the Stony Creek Watershed

2.8 HYDROLOGY

Of the four watersheds that are the focus of this study, Pipe Creek and Stony Creek have USGS stream gages that were active at the time of water quality sampling. Additional flow data were provided by the Upper White River Watershed Project. Killbuck Creek discharge was calculated by measuring the water depth and stream velocity for several stream subsections. This data set contains two years of flow data. Because no flow data exist for the Duck Creek watershed (Arvin, 2004), surrogate flows were established by utilizing data from the Pipe Creek flow gage. This flow was adjusted by utilizing a "drainage area ratio" approach, considering the drainage areas for the respective subwatersheds contributing flow to the location. The resultant estimated flow record will be sufficient for constructing a load duration curve. Figure 2-33 illustrates the locations of the three flow gages that were utilized in this study.

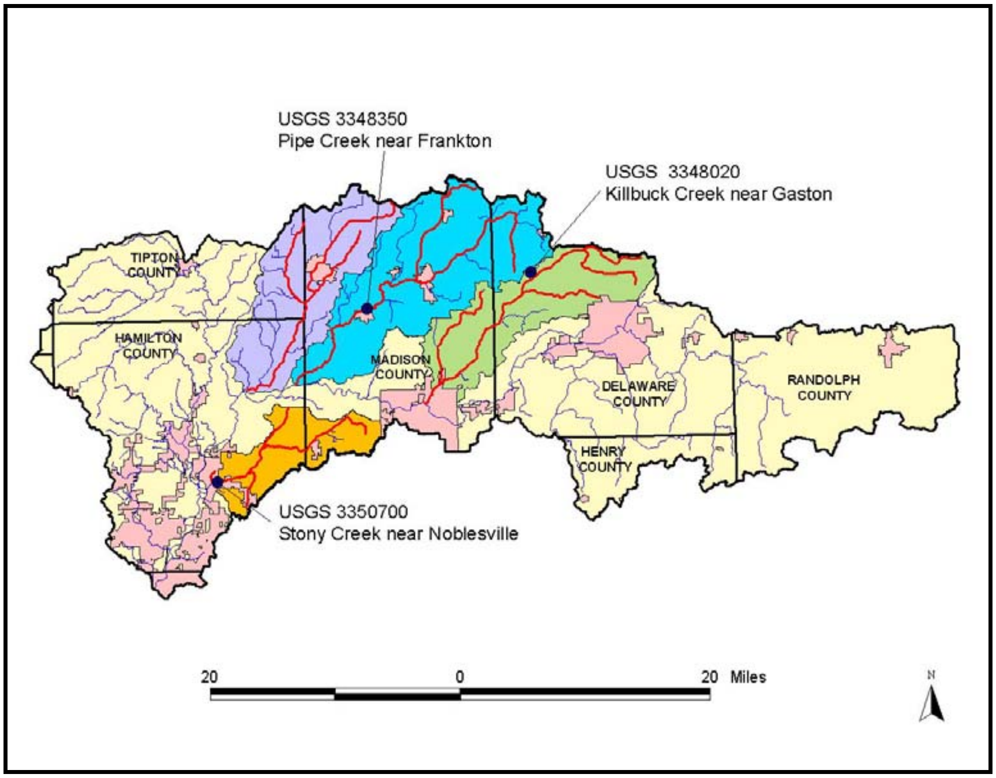

Figure 2-33. USGS Flow Stations in the Study Area

3.0 INVENTORY AND ASSESSMENT OF WATER QUALITY INFORMATION

The Duck Creek, Pipe Creek, Killbuck Creek, and Stony Creek watersheds were listed as impaired on Indiana's 2004 303(d) List for Indiana due to violations of the State's single sample water quality standard for *E. coli* bacteria, an indicator of the presence of pathogens. *E. coli* bacteria counts are used as indicators of the presence of pathogens in Indiana surface waters. IDEM monitors for the presence of *E. coli* as part of the Surface Water Quality Assessment program. Since 1996, the program has utilized a rotating basin approach to water quality planning, monitoring, assessment, reporting, protection, and restoration.

IDEM has sampled water quality data for a total of 56 stations in the four watersheds of concern. In addition to *E. coli* and temperature, some of these stations were sampled for other pollutants, including metals and nutrients. Depending on watershed, the data cover a period of 1996-2004, including the 1998, 2001, and 2004 assessments completed in support of IDEM's 303(d) listing. Figure 3-1 presents the locations of the impairments and surface water quality stations in each watershed.

In addition to IDEM water quality monitoring sites, additional sites were monitored by watershed programs in the Killbuck Creek and Stony Creek watersheds. Six stations in the upper portion of Killbuck Creek were monitored as part of the Upper White River Watershed Project under the direction of the Delaware County Soil and Water Conservation District (2002-2004). The stations were sampled from 2002-2004 and analyzed by the Bureau of Water Quality. The data include discharge, water level, temperature, and rain gage measurements, and chemical and biological parameters, including *E. coli*. Although this study is ongoing and conclusions are not yet complete, data available to date are included in the Killbuck Creek *E. coli* dataset provided in Appendix A. These data were used to evaluate and confirm recent impairment in the Killbuck watershed for the subwatersheds containing the Upper White River Watershed Project stations.

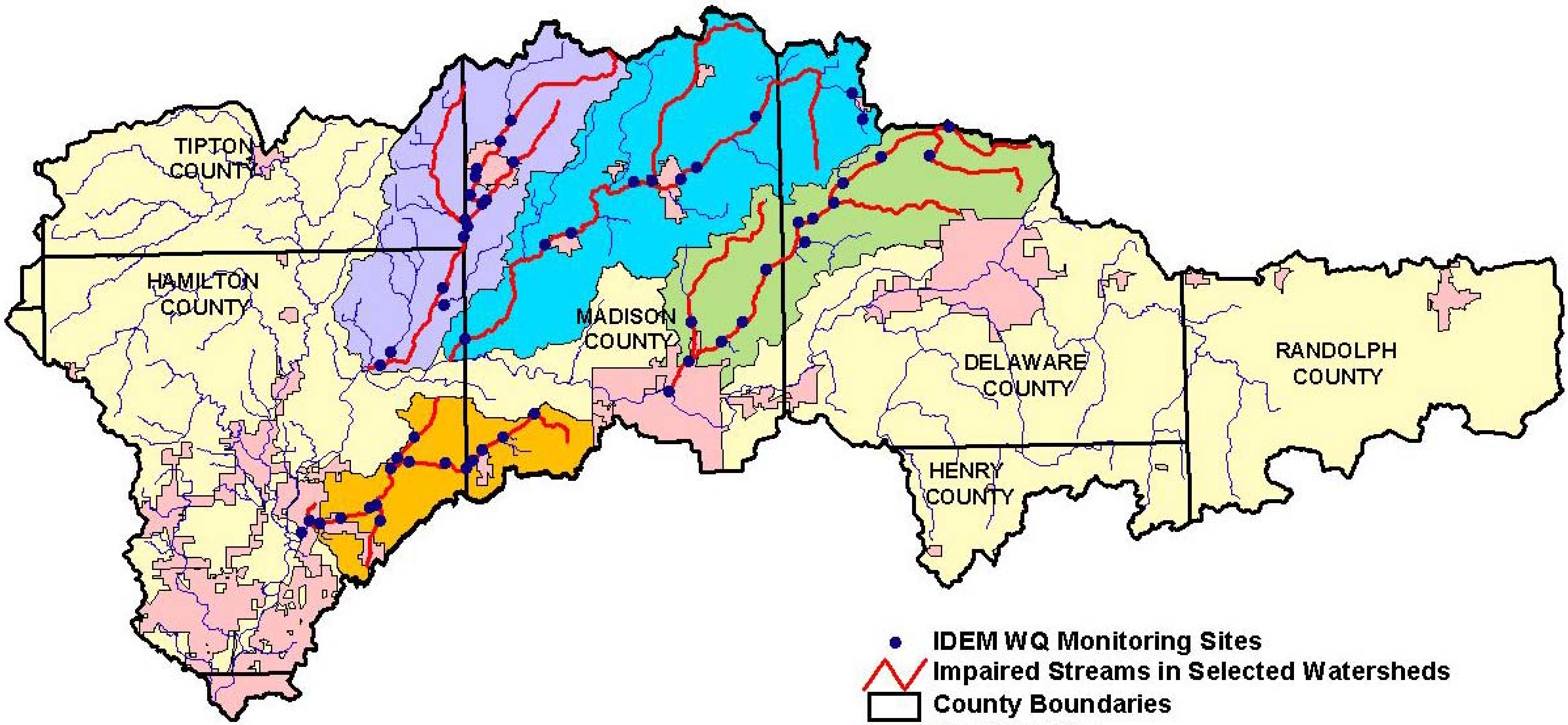

Figure 3-1. Locations of Impairments and IDEM Water Quality Monitoring Sites

In the Stony Creek watershed, a biomonitoring, water quality, and habitat assessment was recently completed by Hamilton County in support of the Stony Creek Watershed Master Plan (Baker and Nelson, 2004). This study included an analysis of fecal coliform counts at nine stations throughout the watershed. These counts have been translated to *E. coli* counts to enable comparisons and evaluations with other available data. These data provide evidence of more recent water quality violations during 2003, supporting a lack of improvement in the Stony Creek watershed.

3.1 EVALUATION OF DATA USING THE GEOMETRIC MEAN STANDARD

The geometric mean standard for *E. coli* states that, based on five samples collected over a thirty-day period, the geometric mean of *E. coli* counts shall not exceed 125 colonies per 100 milliliters. Although not all historical data sets contain data samples at this frequency, some of the data collected in each of the four watersheds in the spring and summer for the 2001 assessment meet this requirement. At stations where at least five samples were collected over a thirty-day period, the geometric mean was calculated and compared to the 125 cfu/100 ml standard. Violations of the geometric mean standard verify the impairment of all four waterbodies. Figure 3-2 demonstrates the location of sites with sufficient data to assess violations of the geometric mean standard and shows the general range of the geometric means at each location.

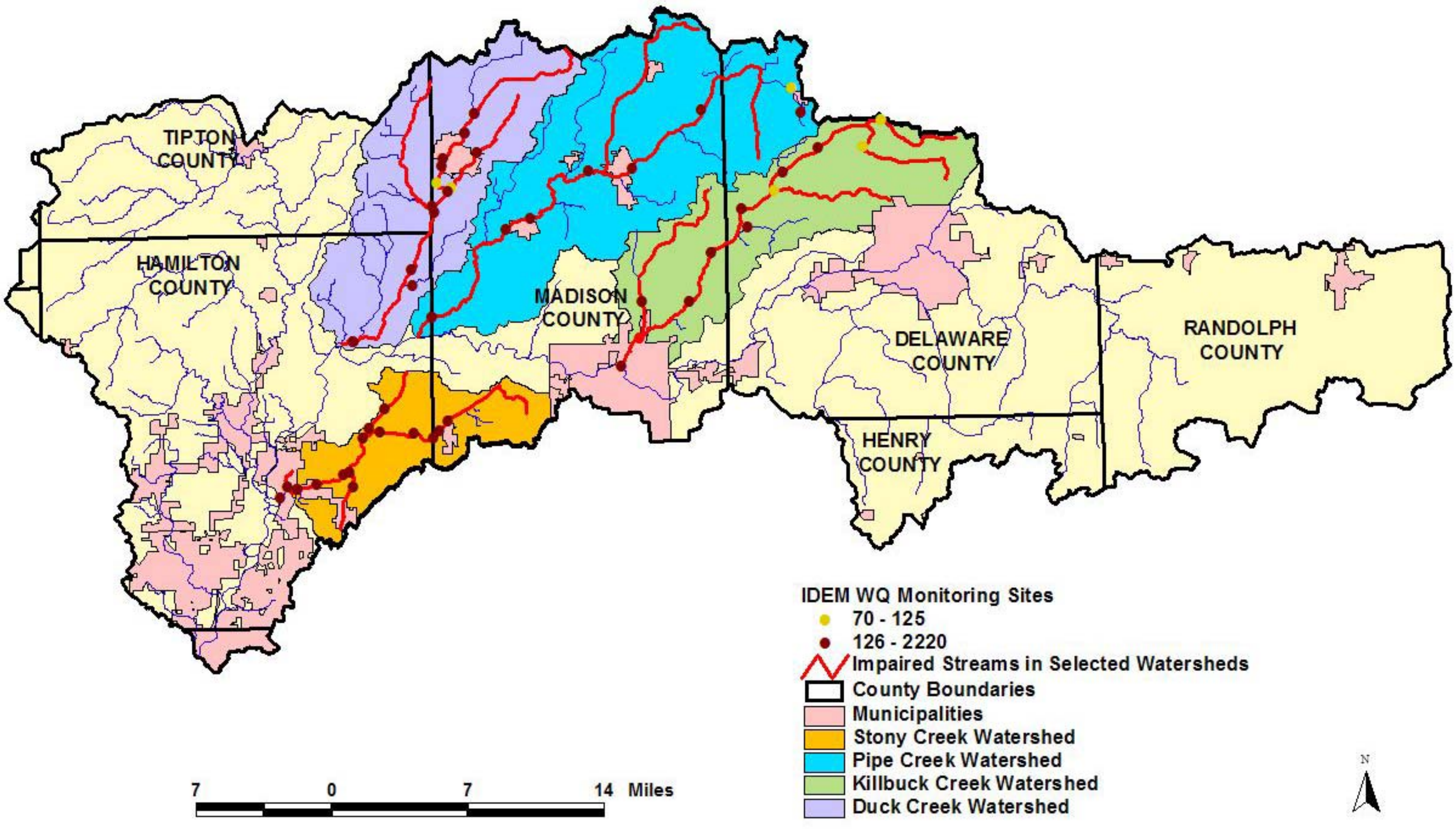

Figure 3-2. Violations of the Geometric Mean Standard (125 cfu/100 ml) for Water Quality Monitoring Stations (Violations shown in dark red)

Figures 3-3 through 3-6 present comparisons of geometric means for water quality stations where sufficient *E. coli* samples were collected over the specified thirty-day period and the extent to which stations are in violation of the standard. For example, in the Stony Creek watershed, of sixteen stations meeting the criteria for comparison, only one station meets the geometric mean standard.

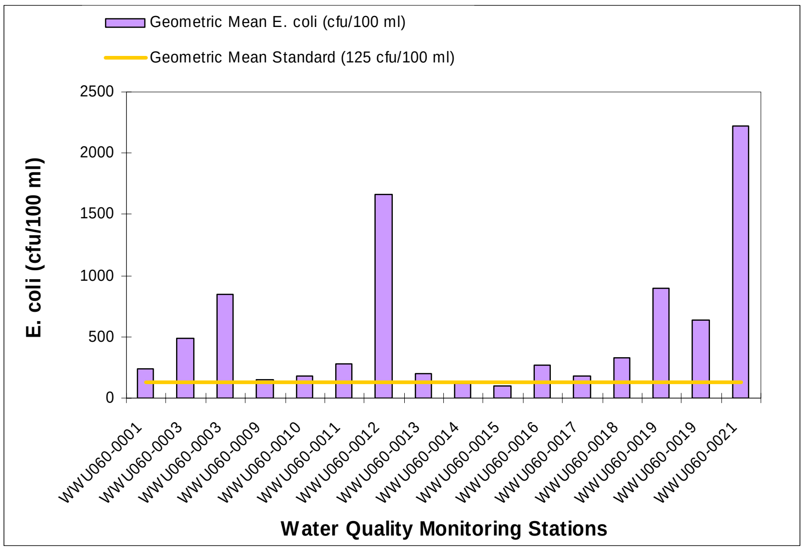

Figure 3-3. Violations of the Geometric Mean Standard for Water Quality Monitoring Stations in the Duck Creek Watershed

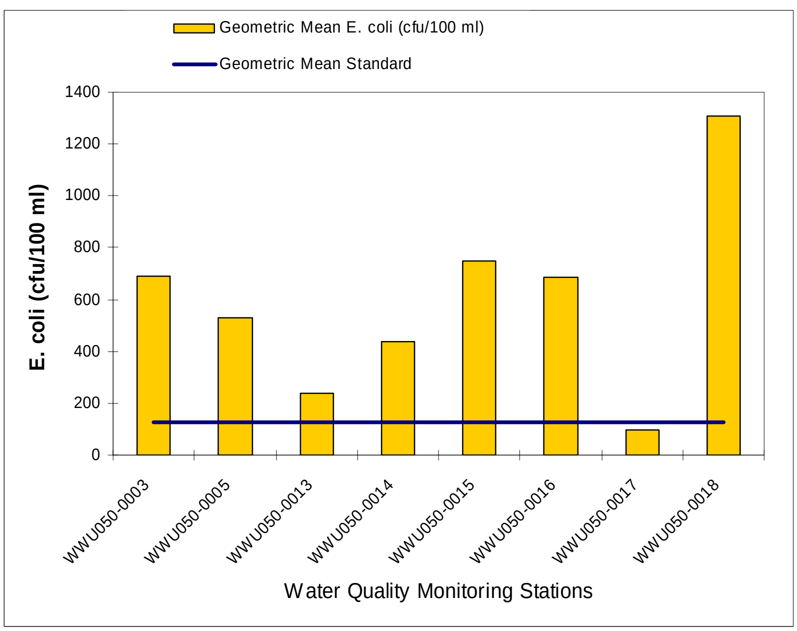

Figure 3-4. Violations of the Geometric Mean Standard for Water Quality Monitoring Stations in the Pipe Creek Watershed

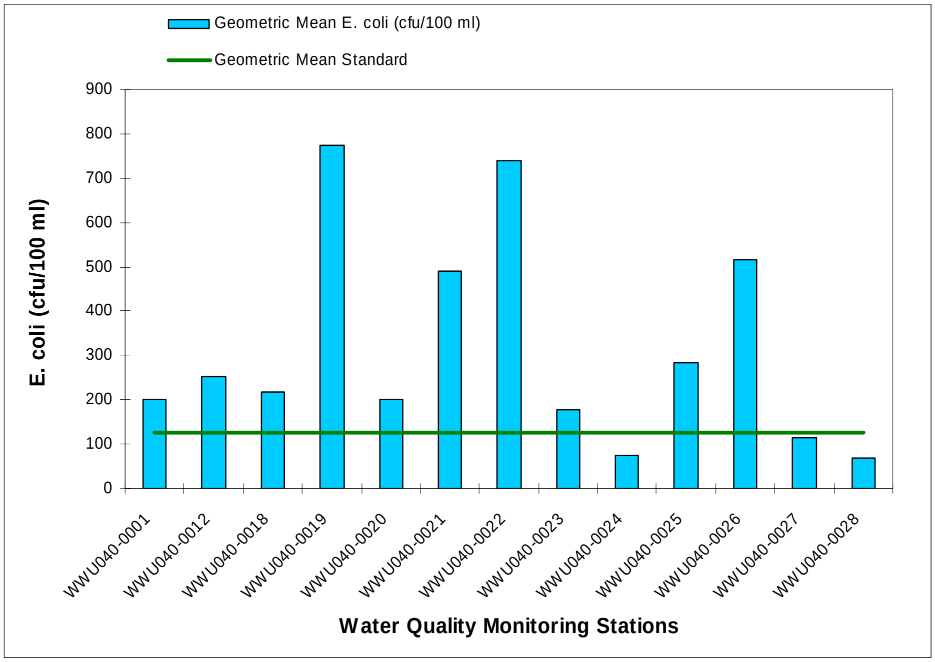

Figure 3-5. Violations of the Geometric Mean Standard for Water Quality Monitoring Stations in the Killbuck Creek Watershed

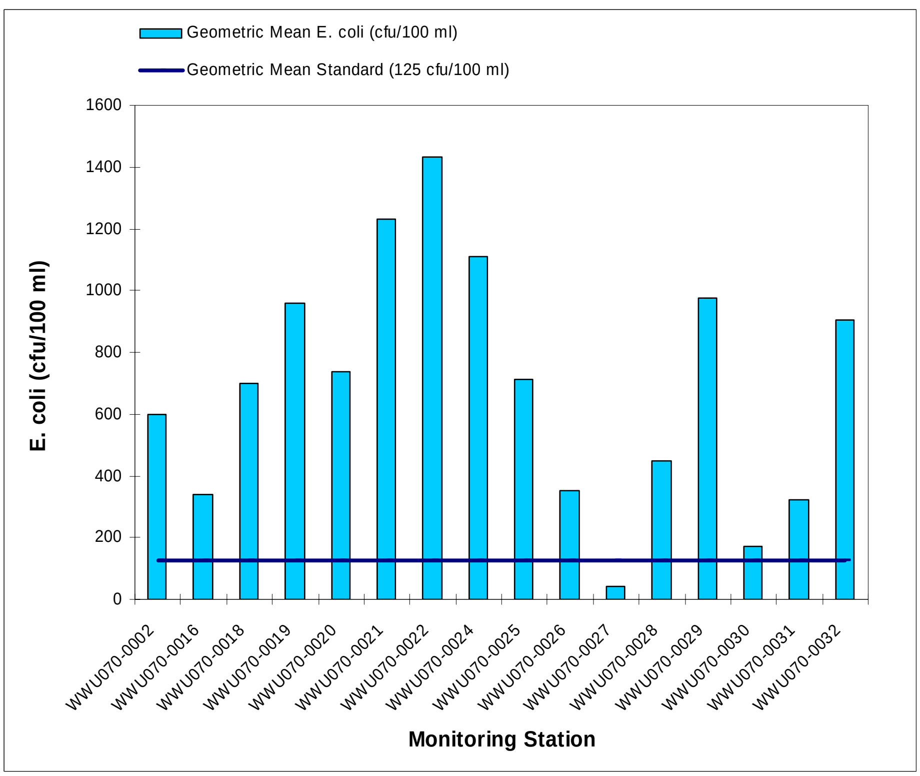

Figure 3-6. Violations of the Geometric Mean Standard for Water Quality Monitoring Stations in the Stony Creek Watershed

3.2 EVALUATION OF DATA USING THE SINGLE SAMPLE STANDARD

The single sample standard applies to all grab samples collected from April 1 through October 31, which is defined as the recreational season. The numeric criteria for *E. coli* in waters designated for recreational use in Indiana is 235 cfu/100 ml. Figure 3-7 demonstrates the frequency of violations of the single sample standard in each of the four watersheds. The average frequency of violations in all four watersheds is 75%. Appendix B includes water quality duration curve plots of the grab samples collected during 2001. Each sample is plotted at the percentile value of the estimated flow at the monitoring location.

3.3 WATER QUALITY DATA USED IN TMDL APPROACH

The maximum *E. coli* counts recorded at each monitoring location were used to estimate the median *E. coli* load for each day and as a starting point for applying reductions necessary to meet the Indiana "Not to Exceed" standard for *E. coli*. Data from 1996 monitoring events was reviewed and the *E. coli* counts at stations with both 1996 and 2001 IDEM data available were fairly consistent in range of values. However, because this dataset was limited in number of records and due to the inconsistent hydrologic profile available for the 1996 sampling dates, the adjusted median flows were much lower than expected. Limiting the data to the 2001 sampling events allowed for calculation of adjusted median flows that more closely matched expected flow values.

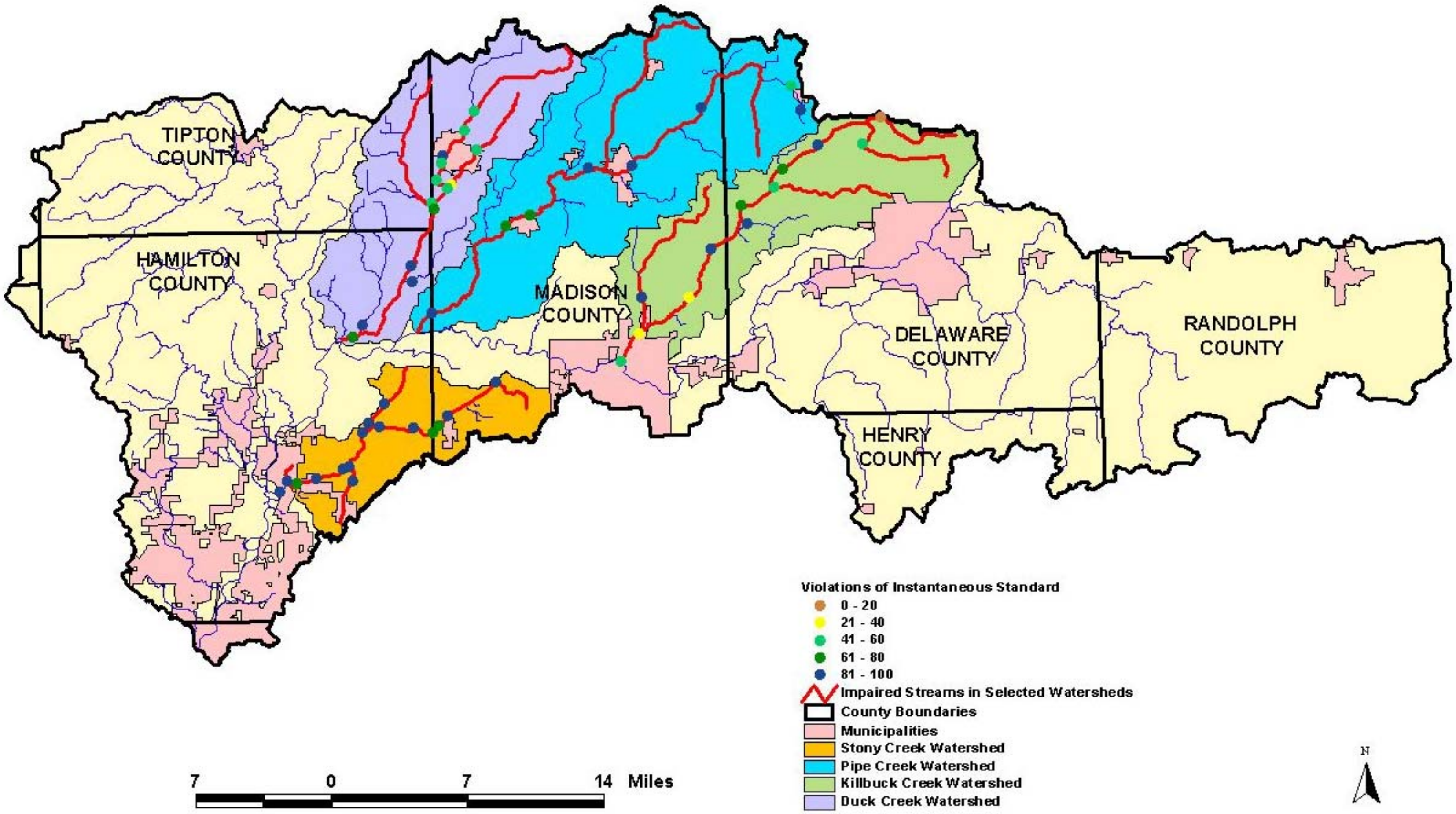

Figure 3-7. Frequency of Violations of Single Sample Standard at IDEM Sampling Sites

4.0 SOURCE ASSESSMENT

A source assessment is used to characterize the known and suspected sources of *E. coli* bacteria in an impaired watershed for use in the water quality analysis and the development of TMDLs. Establishing loading estimates for the suspected sources provides the foundation for allocation of reductions and also for recommended implementation activities. Bacteria sources are generally divided into point and nonpoint sources.

4.1 POINT SOURCES

Point sources are sources that can be associated with a discernable location through which pollutant loads are generally passed to a receiving water body via discrete conveyance, such as a pipe, ditch, channel, or conduit. The term “point source” also includes concentrated animal feeding operations (CAFOs), confined feeding operations (CFOs), combined sewer overflows (CSOs), and stormwater runoff transported via discrete conveyance.

Many point sources, such as wastewater treatment plants (WWTPs), have regulatory permit limits imposed in order to ensure that discharges support and maintain instream water quality standards. Estimation of the regulated *E. coli* loadings from these sources is relatively simple. However, when treatment processes fail, or when wet weather inflows lead to an exceedance of the WWTP and discharge of CSO, raw sewage may bypass the established treatment process and be discharged directly to receiving waters, resulting in violations of the instream water quality standards.

4.1.1 WASTEWATER TREATMENT PLANTS

All National Pollutant Discharge Elimination System (NPDES) permits in the four watersheds were acquired from the IDEM Office of Water Quality. Any NPDES facility having *E. coli* effluent limits includes the respective geometric mean and “never-to-exceed” standards of 125 col/100 mL and 235 col/100 mL as the numeric values for the limits. The Elwood Sewage Treatment Plant in the Duck Creek watershed is the largest municipal discharge in the study area, and is permitted to discharge up to 3.22 MGD. In an Agreed Order between the City of Elwood and IDEM (IDEM, 2002), the City acknowledged that the daily maximum effluent limit for *E. coli* was violated between April and September 2001, a period which coincides with IDEM’s 2001 targeted sampling of *E. coli* in the watershed. There are also four industrial dischargers in the Duck Creek watershed that all provide their effluent to the Elwood facility. No industrial effluent streams in the four watersheds have permit limits for *E. coli*, nor are any of the effluents expected to contain *E. coli*.

The Pipe Creek watershed includes five municipal discharges, one industrial discharge, one commercial process discharge, and two water treatment plant discharges. Four of the five municipal permits have limits and monitoring requirements for *E. coli*, the largest of which is the Alexandria Water Pollution Control Plant, which can discharge up to 1.2 MGD. In addition to the four municipal facilities, the Red Gold Incorporated tomato processing facility also has *E. coli* limits and monitoring requirements. None of the other dischargers have or need *E. coli* limits.

The Killbuck Creek watershed has ten municipal discharges and three industrial discharges. All of the municipal discharges have flow limits below 0.1 MGD and only two of the permits have limits for *E. coli*. Most municipal facilities that discharge less than 1.0 MGD do not currently have *E. coli* limits, but a total residual chlorine limit instead. Previously, facilities with design flows under 1 MGD (typically minor municipals and semi-publics) were not required to have *E. coli* effluent limits or conduct monitoring for *E. coli* bacteria, provided they maintained specific total residual chlorine levels in the chlorine contact tank. The assumption was that as long as chlorine levels were adequate in the chlorine contact tank, the *E. coli* bacteria would be deactivated and compliance with the *E. coli* WQS would be met by default. The original basis for allowing chlorine contact tank requirements to replace bacteria limits was based on fecal coliform, not *E. coli*. No direct correlation between the total residual chlorine levels and *E. coli* bacteria can be conclusively drawn. Further, it has been shown that exceedances of *E. coli* bacteria limits may still occur when the chlorine contact tank requirements are met. *E. coli* limits will be introduced during each facility's next permit cycle.

The Stony Creek watershed includes two municipal discharges, three industrial discharges, and one water treatment plant discharge. The largest municipal discharge, the Lapel Municipal WWTP, has a maximum permitted flow of 0.36 MGD. None of the discharges in the Stony Creek watershed have *E. coli* limits. Most municipal facilities that discharge less than 1.0 MGD do not currently have *E. coli* limits, but a total residual chlorine limit instead. *E. coli* limits will be introduced during each facility's next permit cycle.

Table 4-1 lists each watershed's NPDES facilities that may have the potential for discharging *E. coli*. Figures 4-1 through 4-4 show the locations of these facilities within each watershed (IDEM, 2004a). For purposes of estimating the *E. coli* loads from these facilities, full permitted design flows were assumed, along with a constant level of 125 *E. coli* counts/100 mL (geometric mean standard). The calculated loads are also shown in Table 4-1.

Table 4-1. NPDES Facilities with the Potential to Discharge *E. coli* to the Duck Creek, Pipe Creek, Killbuck Creek, and Stony Creek Watersheds

NPDES ID	COUNTY	WATERSHED	FACILITY NAME	RECEIVING WATER	FLOW (MGD)	E. coli Load (count / day)
IN0032719	MADISON	DUCK	ELWOOD SEWAGE TREATMENT PLANT	BIG DUCK CREEK	3.22	1.52E+10
IN0020044	MADISON	PIPE	ALEXANDRIA WATER POLLUTION C P	PIPE CREEK	1.2	5.68E+09
IN0020028	MADISON	PIPE	FRANKTON MUNICIPAL WWTP	PIPE CREEK	0.286	1.35E+09
IN0020338	DELAWARE	PIPE	GASTON MUNICIPAL WWTP	PIPE CREEK	0.3	1.42E+09
IN0038857	DELAWARE	PIPE	I 69 AUTO TRUCK PLAZA INC	YEAGER-FINLEY-MANARD DITCH	0.01	4.74E+07
IN0031356	DELAWARE	PIPE	IDOT PIPE CREEK REST PARK I 69	RICHARDS DITCH	0.025	1.19E+08
IN0036587	MADISON	PIPE	RED GOLD INCORPORATED	LILLY CREEK	0.234*	1.11E+09
IN0031933	DELAWARE	KILLBUCK	COUNTRY ACRES MOBILE HOME PARK	KILLBUCK CREEK	0.0198	9.37E+07
IN0025402	DELAWARE	KILLBUCK	COUNTRY VILLAGE SUBDIVISION	KILLBUCK CREEK	0.0777	3.68E+08
IN0043974	DELAWARE	KILLBUCK	DELAWARE ACRES MHP	MUD CREEK	0.03	1.42E+08
IN0037184	DELAWARE	KILLBUCK	DELTA HIGH SCHOOL	MUD CREEK	0.0435	2.06E+08
IN0038407	DELAWARE	KILLBUCK	JACKSON MOBILE HOME PARK	JAKE'S CREEK	0.0283	1.34E+08
IN0060011	MADISON	KILLBUCK	KENNEDY MACHINE & TOOL WWTP	OLD CANAL VIA DITCH	0.005	2.37E+07
IN0061301	DELAWARE	KILLBUCK	MOUNT PLEASANT UTILITIES LLC	PLEASANT RUN CREEK	0.04	1.89E+08
IN0053627	MADISON	KILLBUCK	RESTING WHEELS MOB. HOME COURT	LITTLE KILLBUCK CREEK	0.01155	5.47E+07
INL025364	DELAWARE	KILLBUCK	ROYERTON ELEMENTARY SCHOOL	UNNAMED TRIB	0.037	1.75E+08
IN0025151	DELAWARE	KILLBUCK	WES-DEL SENIOR HIGH SCHOOL	THURSTON DITCH	0.0312	1.48E+08
IN0020087	MADISON	STONY	LAPEL MUNICIPAL WWTP	STONY CREEK	0.36	1.70E+09
IN0025526	HAMILTON	STONY	TALL TIMBER MOBILE HOME PARK	STONY CREEK VIA UNNAMED TRIB	0.0126	2.37E+07

*average of reported values from DMR data

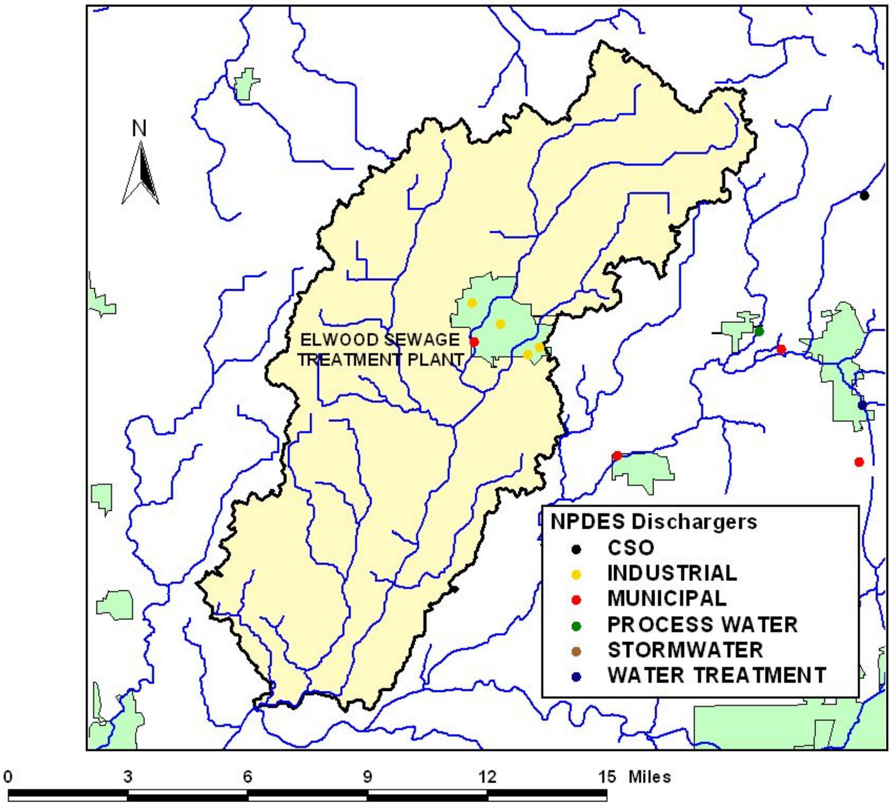

Figure 4-1 NPDES Facilities in the Duck Creek Watershed

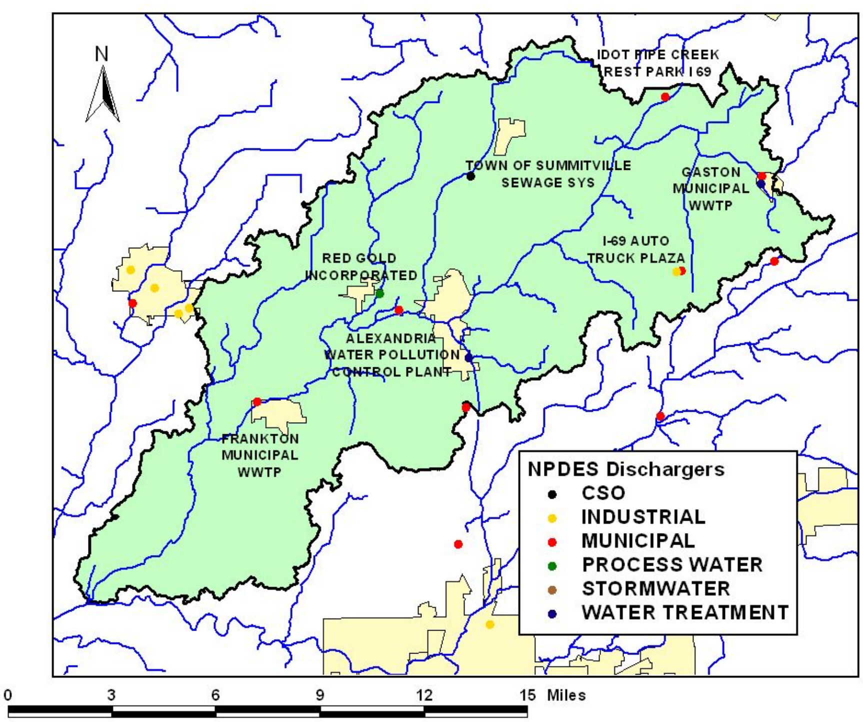

Figure 4-2. NPDES Facilities in the Pipe Creek Watershed

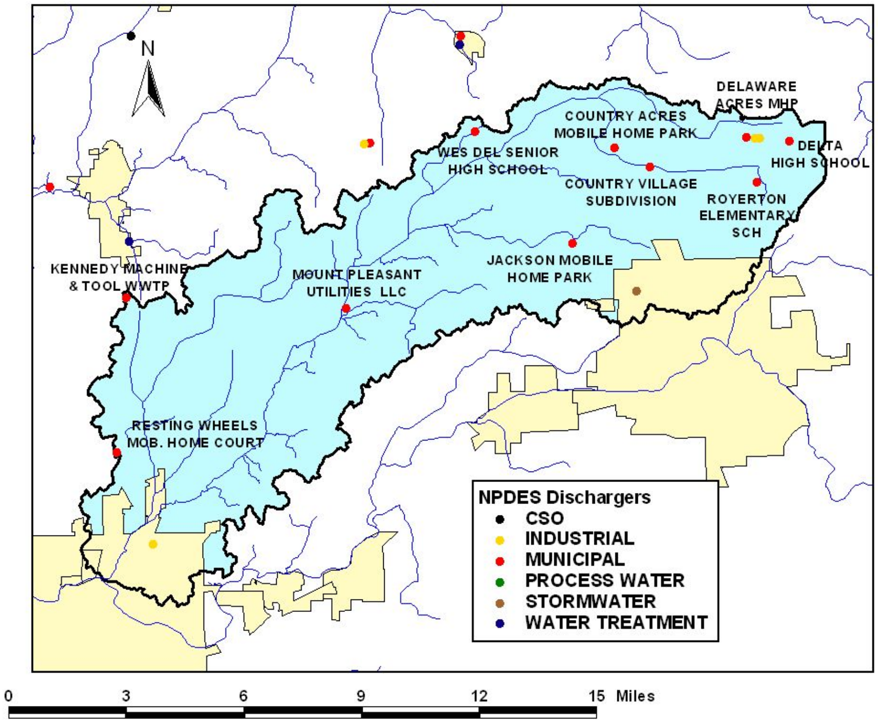

Figure 4-3. NPDES Facilities in the Killbuck Creek Watershed

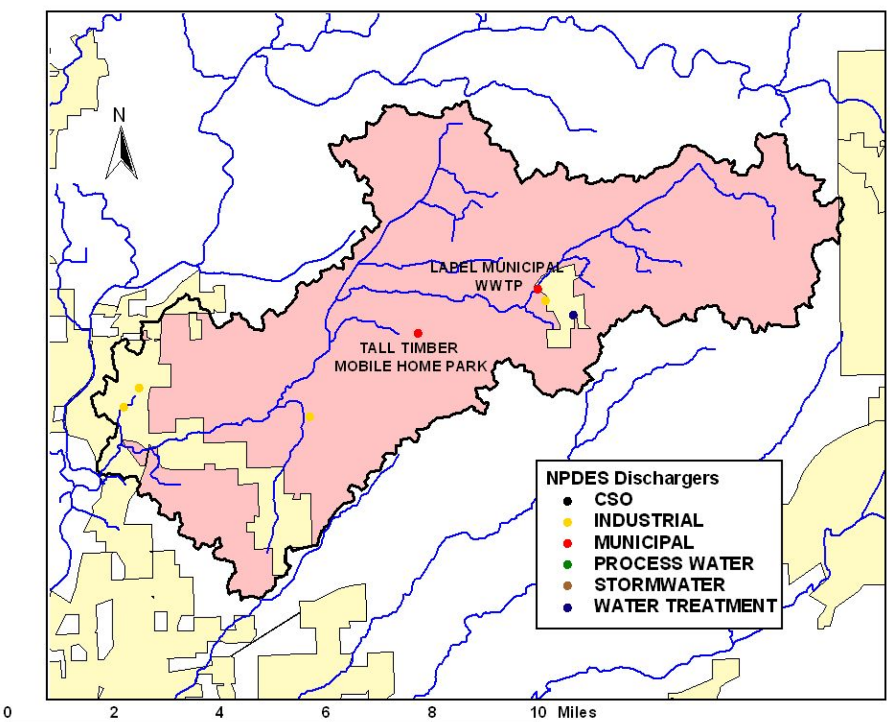

Figure 4-4. NPDES Facilities in the Stony Creek Watershed

4.1.2 COMBINED SEWER OVERFLOWS

Municipal areas where connections between sanitary and storm sewers exist typically experience combined sewer overflows (CSO) during storm events. During heavy precipitation, local runoff can overwhelm storm discharge capacity, forcing stormwater to back into the sanitary sewer. Untreated domestic waste from the sanitary sewer can then be flushed directly into a waterbody, resulting in high levels of indicator bacteria such as *E. coli.*

IDEM regulates CSOs in Indiana through the state's NPDES program by implementation of strategies to maintain and manage existing CSO systems. One key component of this program is locating all CSO outfalls for tracking purposes. IDEM records indicate that the City of Elwood has 14 CSO outfalls located in the Duck Creek watershed. City of Elwood WWTP personnel (Washburn, 2004) provided locations of these CSO outfalls, which are shown in Figure 4-5. In the Agreed Order with IDEM (IDEM, 2002), the City of Elwood acknowledged that both wet weather and dry weather discharges from its CSO outfalls occurred during the period of IDEM's 2001 targeted *E. coli* sampling (April – September). The City also agreed to submit a revised CSO Plan for improving operation and maintenance of its CSO outfall structures to IDEM by June 30, 2005. As such, implementation of this CSO Plan is expected to result in *E. coli* load reductions to Duck Creek.

Personnel from the Pipe Creek watershed communities of Alexandria, Frankton, and Summitville (Pierce (2004), Seal (2004), and Dow (2005)) provided location information for CSO outfalls in those communities. According to that information, Alexandria and Frankton each currently have only one active CSO outfall, while the 2 Summitville CSOs are documented within that city's NPDES permit. CSO Long Term Control Plans (LTCPs) for those three communities were submitted on May 3, 2002 (Frankton), June 12, 2002 (Alexandria), and October 1, 2003 (Summitville). Figure 4-6 shows the locations of these CSO outfalls within the Pipe Creek watershed.

Discussions with the Hamilton County Surveyor (Thompson, 2004) and the City of Lapel's contracted WWTP design engineer (Shuck, 2004) provided information on CSOs in the Stony Creek watershed cities of Noblesville and Lapel. For Noblesville, two of the city's eight CSO outfalls discharge to the North Tributary subwatershed of Stony Creek. Noblesville's LTCP was submitted on August 29, 2003. In Lapel, no CSO outfalls exist. However, the municipal WWTP does have a wet well that could overflow and discharge to either a stormwater outfall or the

WWTP outfall, although this condition has not been recently observed. The Lapel wet well overflow condition is expected to be corrected within 2005. Figure 4-7 shows the locations of the Noblesville CSO outfalls and the Lapel WWTP in the Stony Creek watershed.

While parts of both Anderson and Muncie are contained within the hydrologic boundary of the Killbuck Creek watershed, the CSO outfalls for both of the cities discharge to the West Fork White River. As such, the Killbuck Creek watershed contains no known CSO outfalls.

A CSO community that believes it is not possible to meet existing water quality based requirements may develop information that supports a use attainability analysis. Such information may be included in the CSO LTCP. The use attainability analysis may result in the revision of designated uses and associated criteria if the applicable requirements of state and federal law, including 40 CFR 131.10 are met. However, states may remove a designated use that is not an existing use. Additionally, any existing use, even if not a designated use, must be protected. Furthermore, downstream water quality standards must be maintained and protected.

In order to estimate CSO loads from these sources, some assumptions were made regarding typical CSO discharge quality and volume. Typical discharge *E. coli* concentrations were assumed to be equal to the average of the values used for the Fall Creek and Pleasant Run TMDLs (IDEM, 2003 and IDEM, 2003a), which were determined from targeted CSO *E. coli* sampling efforts in 2001. This value was calculated as 1.07×10^6 counts/100 mL. Daily wet weather CSO volume was estimated using the year 2000 census population from each discharging community, an assumption of 75 gallons of wastewater generated per capita-day (Geldreich, 1978), and best professional judgment (BPJ) estimates of (a) 90% of persons in urban areas sewered, (b) 50% of CSO volume coming from sewage, and (c) 4 hours of discharge time per wet weather day. Finally, based on the locations of the CSO outfalls and the areal expanse of each discharging community, estimates of the percentage of each community serviced by the CSOs were made. Table 4-2 shows the five CSO communities identified within the Duck Creek, Pipe Creek, and Stony Creek watersheds, the estimated percentage of each community serviced by the CSOs in the watersheds, and the resultant estimated daily *E. coli* loading from each community.

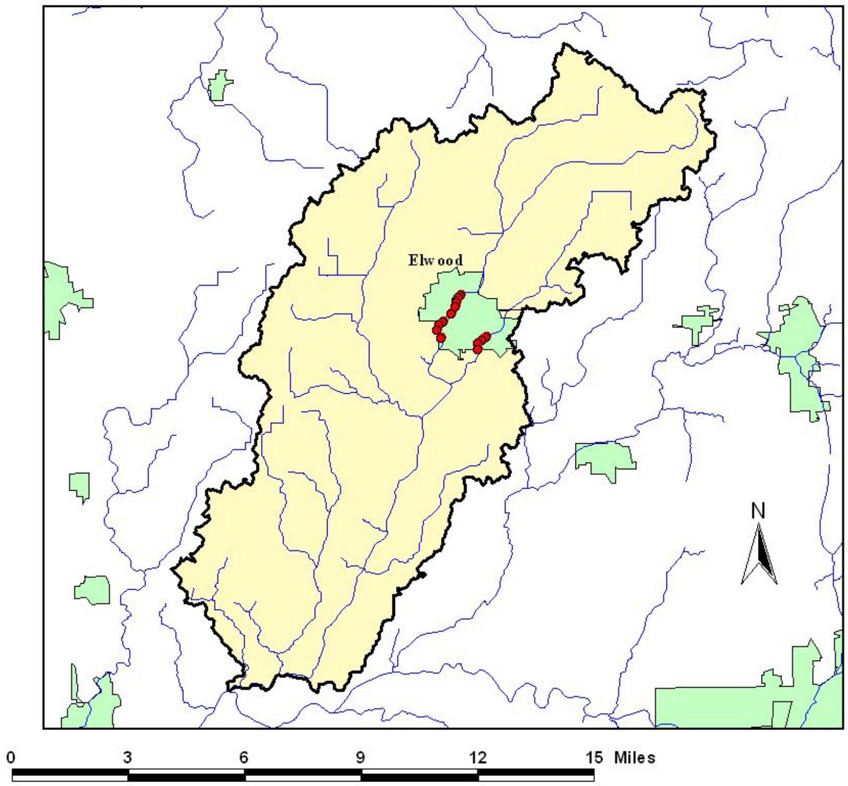

Figure 4-5. CSO Locations (red) in the Duck Creek Watershed

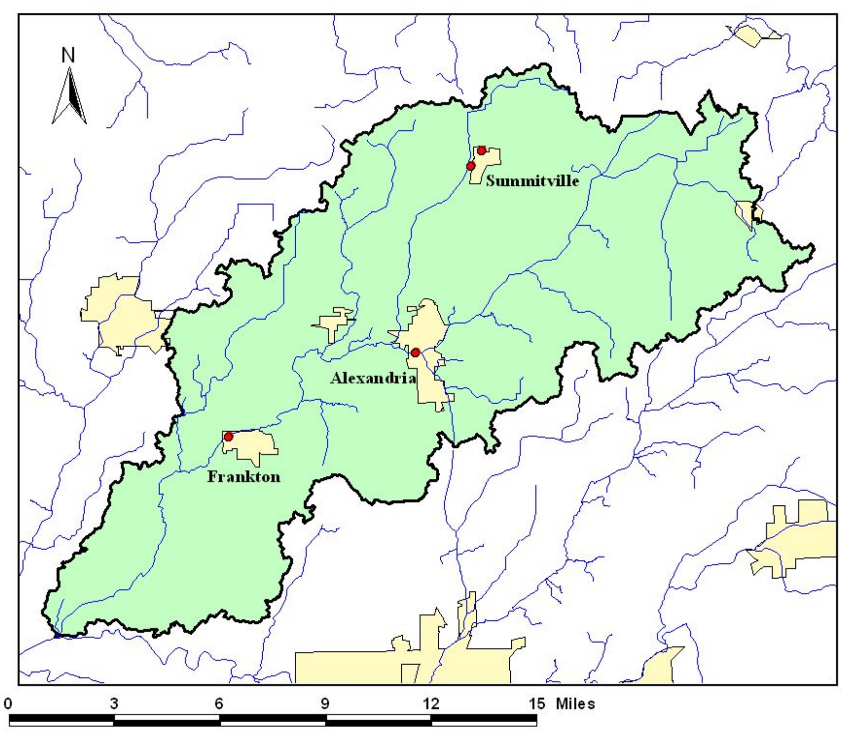

Figure 4-6. CSO Locations (red) in the Pipe Creek Watershed

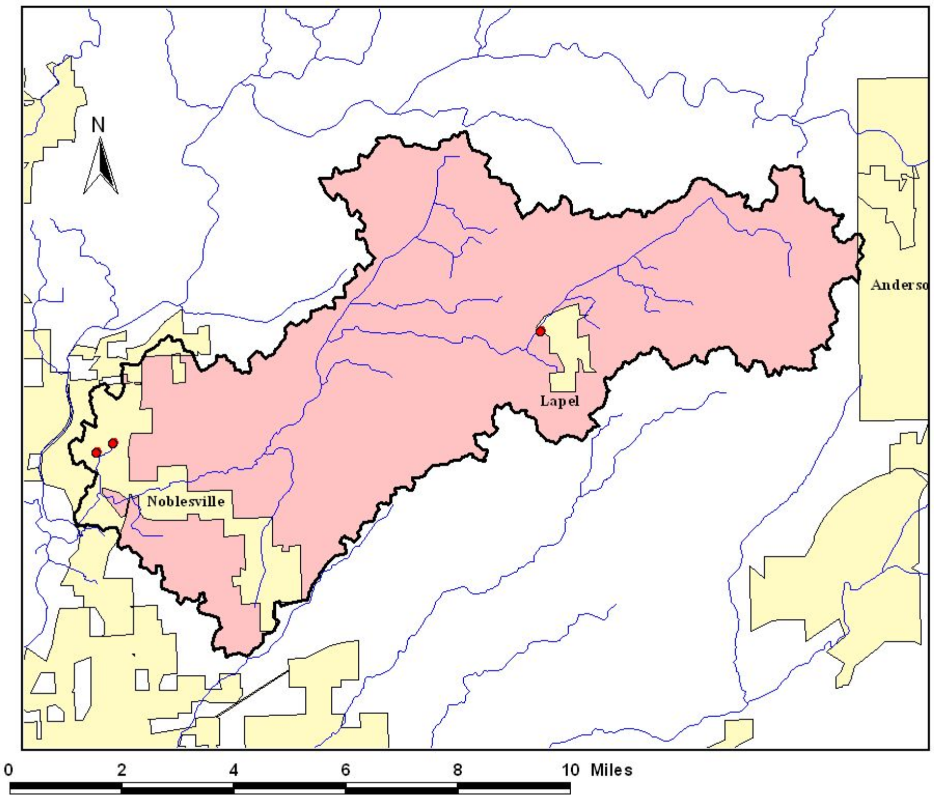

Figure 4-7 CSO Locations (red) in the Stony Creek Watershed

Table 4-2 Estimated *E. coli* Loads from Five CSO Communities in the Duck Creek, Pipe Creek, and Stony Creek Watersheds

Community	Watershed	2000 Population	% of City Contributing to CSOs	E. Coli Load (count/day)
Summitville	Pipe Cr	1,090	100%	2.49E+11
Alexandria	Pipe Cr	6,260	50%	7.14E+11
Frankton	Pipe Cr	1,905	100%	4.35E+11
Elwood	Duck Cr	9,737	100%	2.22E+12
Noblesville	Stony Cr	28,590	20%	1.31E+12

4.1.3 ANIMAL FEEDING OPERATIONS

Concentrated Animal Feeding Operations (CAFOs) and Confined Feeding Operations (CFOs) are permitted livestock facilities. In Indiana, a CFO is defined when a minimum number of animal units, i.e. at least 300 cattle, 600 swine or sheep, or 30,000 fowl, are confined at the facility. CAFOs are larger, federally designated facilities. CAFOs and CFOs produce significant volumes of animal manure, and are potential sources of *E. coli* bacteria. Animal manure generated at CAFO/CFO facilities is frequently applied to pasture and row crop lands adjacent to, or in close proximity to, the facility. Location of these facilities within a watershed can help to identify row crop and pasture lands that may be at a higher risk of exporting *E. coli* bacteria to receiving waters. A point location layer of Indiana CAFO/CFO facilities was acquired from the IGS website (IDEM, 2004b). The layer identifies 15 active facilities in the Duck Creek, Pipe Creek, Killbuck Creek, and Stony Creek watersheds. Further correspondence with IDEM CAFO/CFO permitting personnel (IDEM, 2005) revealed that two of those facilities have since been voided from the system. Table 4-3 lists the remaining 13 active facilities in the four watersheds. Only one of these facilities, Willemsen Dairy, is currently designated as a CAFO. A second facility, Simmermon Farms #1, is currently operating in Indiana's CFO program and is exempted from CAFO status until 2006. Figures 4-8 through 4-11 show the facility locations in each of the watersheds. Active CAFOs and CFOs are more likely to be continual potential sources of *E. coli*. Inactive or voided CAFO/CFO permits, while possibly still acting as nutrient sources in the watersheds, are probably less significant as current sources of *E. coli*.

The *E. coli* load from CAFOs and CFOs was estimated using the number and type of animals associated with each facility (IDEM, 2005) along with estimates of the daily *E. coli* load per animal, which was calculated from American Society of Agricultural Engineers (ASAE, 1999) data on mass of manure produced per 1000 kg animal unit, typical animal masses, typical rates of fecal coliform per mass of manure, and a factor of 0.9 to convert from fecal coliform to *E. coli*. Table 4-4 shows the ASAE data and resultant estimates of daily *E. coli* load per animal.

Table 4-5 shows the number and type of animals associated with each facility and the total daily *E. coli* load calculated for each facility. This represents the total potential conservative daily *E. coli* load from each facility. For purposes of estimating the daily *E. coli* load that could be transported to receiving streams, it was assumed that 90% of all manure produced at CAFOs and CFOs is collected and used for fertilizer on adjacent row crop and pasture lands. The remaining 10% is assumed to be located at the facilities and the associated *E. coli* load is attributed to the CAFO and CFO point locations via runoff.

Table 4-3. Active CAFOs/CFOs in the Duck Creek, Pipe Creek, Killbuck Creek, and Stony Creek Watersheds

Log #	County	Watershed	Farm Name
1419	Hamilton	Duck	AMORA SOW UNIT
3057	Hamilton	Duck	BRYANT PREMIUM PORT LLC
802	Madison	Duck	WILLIAMS FARMS INC
4643	Madison	Duck	WIMMER FARMS
1011	Tipton	Duck	IDLEWINE
3690	Delaware	Killbuck	JACOBS FARM
2729	Delaware	Pipe	DALE K RINKER
938	Madison	Pipe	SHUTER SUNSET FARMS
2389	Madison	Pipe	SIMMERMON FARMS #2
3540	Madison	Pipe	MCCORD FARMS INC #1
6199	Madison	Pipe	WILLEMSEN DAIRY
504	Hamilton	Stony	ROBERT M ANDERSON
1957	Madison	Stony	SIMMERMON FARMS #1

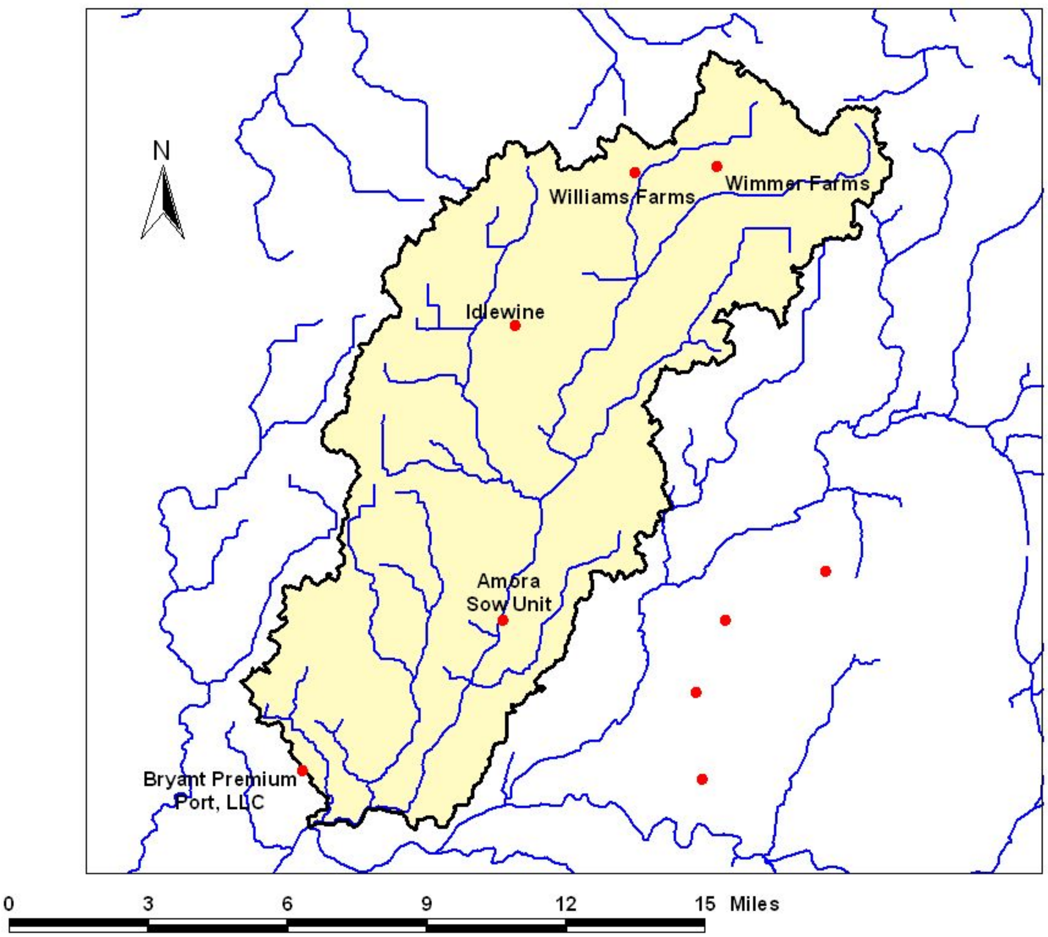

Figure 4-8. Active CAFO/CFO Locations in the Duck Creek Watershed

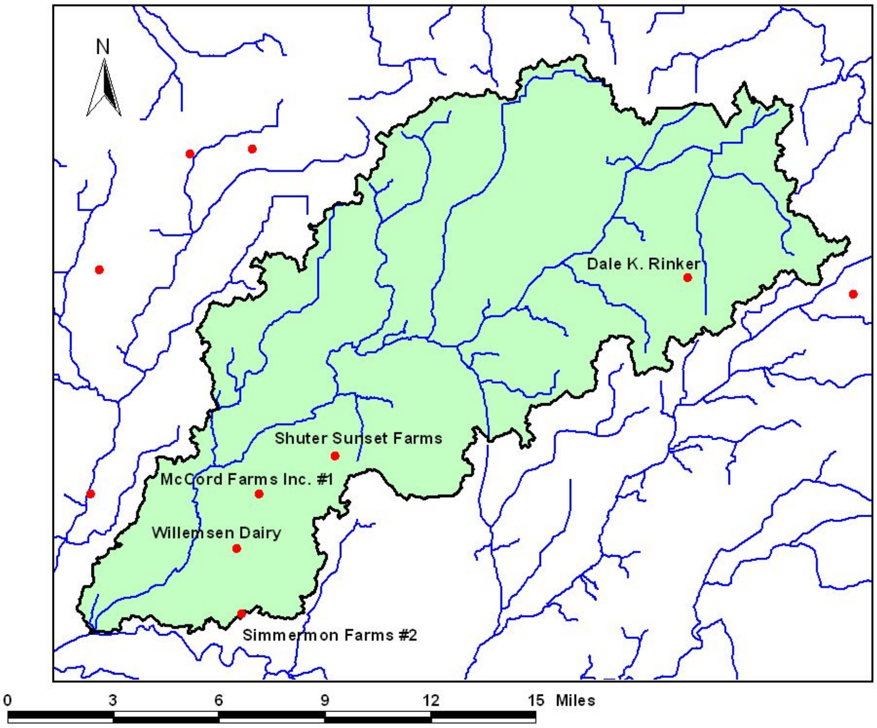

Figure 4-9. Active CAFO/CFO Locations in the Pipe Creek Watershed

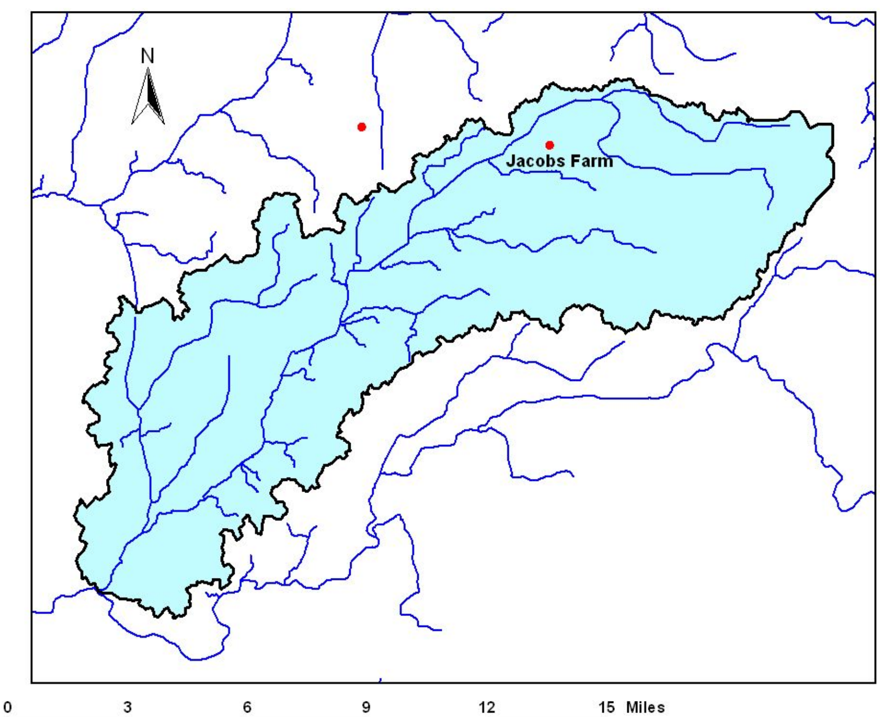

Figure 4-10. Active CAFO/CFO Locations in the Killbuck Creek Watershed

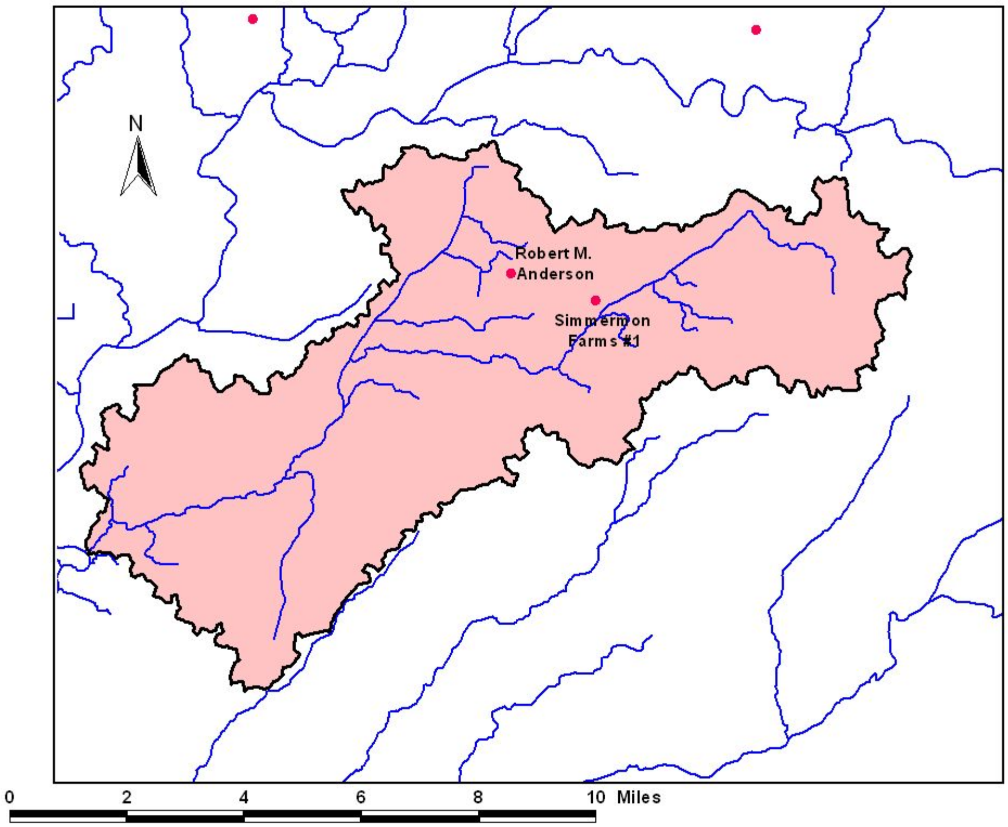

Figure 4-11. Active CAFO/CFO Locations in the Stony Creek Watershed

Table 4-4. Manure Production Rates, Animal Masses, Bacterial Loading Rates, and Estimated *E. coli* Loads from Cows, Pigs, and Sheep (ASAE, 1999)

Statistic	Beef	Milk	Other Cow	Swine	Sheep
Total Manure (kg/1000 kg-d)	58	86	72	84	40
Typical Animal Mass (kg)	360	640	500	61	27
Total Manure (kg/animal-d)	20.88	55.04	36	5.124	1.08
Fecal Coliform Rate (col / 1000 kg)	2.8E+11	1.6E+11	2.2E+11	1.8E+11	4.5E+11
Fecal Coliform Rate (col / kg manure)	4.83E+09	1.86E+09	3.056E+09	2.14E+09	1.13E+10
EColi Rate (col/ kg manure)	4.34E+09	1.67E+09	2.75E+09	1.93E+09	1.01E+10
Ecoli Load (col / animal-day)	9.07E+10	9.22E+10	9.9E+10	9.88E+09	1.09E+10

Table 4-5. Number of Animals Associated with Duck Creek, Pipe Creek, Killbuck Creek, and Stony Creek CAFOs and CFOs (IDEM, 2005) and Estimates of *E. coli* Loads from Those Facilities

Farm Name	Nursery Pigs	Grower/ Finishers	Sows/ Boars	Beef	Beef Calves	Dairy	Total Pigs	Total Cows	Total EColi Load (count/day)	10% Total EColi Load (count/day)
AMORA SOW UNIT	500	500	280	0	0	0	1280	0	1.26E+13	1.26E+12
BRYANT PREMIUM PORT LLC	400	220	16	0	0	0	636	0	6.28E+12	6.28E+11
WILLIAMS FARMS INC	640	370	87	0	0	0	1097	0	1.08E+13	1.08E+12
WIMMER FARMS	400	1575	304	0	0	0	2279	0	2.25E+13	2.25E+12
IDLEWINE	0	1520	0	0	0	0	1520	0	1.50E+13	1.50E+12
JACOBS FARM	600	1700	300	0	0	0	2600	0	2.57E+13	2.57E+12
DALE K RINKER	300	600	64	0	0	0	964	0	9.53E+12	9.53E+11
SHUTER SUNSET FARMS	150	850	0	87	30	0	1000	117	2.05E+13	2.05E+12
SIMMERMON FARMS #2	1550	0	532	0	0	0	2082	0	2.06E+13	2.06E+12
MCCORD FARMS INC #1	0	0	0	500	0	0	0	500	4.54E+13	4.54E+12
WILLEMSEN DAIRY	0	0	0	0	0	1200	0	1200	1.11E+14	1.11E+13
ROBERT M ANDERSON	500	1000	0	0	0	0	1500	0	1.48E+13	1.48E+12
SIMMERMON FARMS #1	0	2850	0	0	0	0	2850	0	2.82E+13	2.82E+12

4.1.4 MS4 STORMWATER COMMUNITIES

E. coli bacteria loads to receiving waters can be supplemented by stormwater runoff, as bacterial matter can accumulate on land surfaces and wash off during wet weather events. Under Phase II of the NPDES stormwater program, certain smaller urbanized areas that contain Municipal Separate Storm Sewer Systems (MS4s) are required to apply for a NPDES permit and to establish stormwater management plans that entail the implementation of mitigation controls. MS4 permits are being issued in the state of Indiana. Guidelines for MS4 permits and timelines are outlined in Indiana's Municipal Separate Storm Sewer System (MS4) Rule 13 (327 IAC 15-13-10 and 327 IAC 15-13-11). Once these permits have been issued and implemented, they will improve water quality and address storm water impacts in the related watersheds. The Duck Creek, Pipe Creek, Killbuck Creek, and Stony Creek watersheds contain parts of four communities (Anderson, Muncie, Noblesville, and Alexandria) and three counties (Delaware, Hamilton, and Madison) that are designated as NPDES Phase II MS4 entities (IDEM, 2004c).

E. coli loads from stormwater would be expected from a number of activities, such as intermingling of stormwater with raw sewage in CSOs, illegal or failing connections of septic systems to MS4s, transport of domestic and wildlife fecal matter via runoff, and wash-off of manure-based fertilizer from urban residential lawns and parks, to name a few. With the exception of fertilizer wash-off, *E. coli* loads from each of the above activities are explicitly estimated as individual source categories for this TMDL assessment. Discussions with Madison County stormwater personnel (Martin, 2005) have indicated that fertilizer wash-off is not a prevalent condition within the study area. As such, stormwater runoff from MS4 entities within the Duck Creek, Pipe Creek, Killbuck Creek, and Stony Creek watersheds will not be considered as a separate source category for this analysis.

4.1.5 STRAIGHT PIPES

Illicit discharges, or systems that discharge raw sewage to streams without treatment, are known as "straight pipes". Because IDEM regulates discharges to streams through the NPDES program, straight pipes discharge without a NPDES permit and are illegal. Section 2.2.4 contains information regarding Indiana's NPDES program. In areas without access to central sewer systems, onsite septic systems should be approved and permitted by the Indiana Department of Health. See Table 4-1 for permitted discharges to Duck, Killbuck, Pipe, and Stony Creek watersheds. According to the Hamilton County Health Department (McNulty, 2005), although there are not currently any known straight pipes in the area, Health Department staff do occasionally find wastewater connections from homes, typically older homes in very rural areas, leading directly into a stream. When such a situation arises, the Health Department performs a confirmation with a water sample and a dye study. All connections discharging untreated wastewater are illegal and immediate action, in the form of septic system installation, is required within thirty days. The *E. coli* contributions associated with straight pipes are considered in the overall approach to estimating loads from septic systems.

4.2 NONPOINT SOURCES

Nonpoint sources of bacteria are diffuse and cannot be identified as entering the waterbody at a single, discrete location. Nonpoint sources typically involve land activities that contribute bacteria to waterbodies via runoff during precipitation events. As such, nonpoint sources are much more difficult to identify and quantify than are point sources. For the Duck Creek, Pipe Creek, Killbuck Creek, and Stony Creek watersheds, significant nonpoint sources of *E. coli* include failing septic systems, runoff from agriculture row crop and pasture lands, wildlife, and domestic pet waste.

4.2.1 SEPTIC SYSTEMS

On-site septic systems that are appropriately constructed and maintained generally do not contribute *E. coli* loadings to surface waters. In central Indiana, however, there are a number of factors that can play a role in septic system failures, such as high seasonal water tables, limited leach field transmissivity due to areas of compact glacial till and bedrock interference, and high transmissivity due to leach field interaction with quickly draining soils. When septic systems fail, raw sewage may be transported to receiving surface waters before sufficient bacterial decay is completed. The presence of agricultural tile drains throughout central Indiana is another factor that tends to exacerbate *E. coli* loading from septic systems, as some residential septic systems have been illegally connected to tile drains rather than to constructed leach fields. *E. coli* loads from these illegal connections proceed much more quickly to receiving streams than loads from properly constructed septic systems.

Additionally, there is anecdotal evidence (Martin, 2005) that some septic systems for newer developments in the study area are experiencing leach field interference with retired and/or abandoned tile drains. This has become evident as some of these abandoned tile drains have collapsed, creating limited transmissivity conditions that, in turn, have caused septic system backups during wet weather events. Given the existence of this scenario, it stands to reason that a number of these newly developed systems that are not presently failing are interacting with abandoned tile drains and contributing non-decayed *E. coli* loads to receiving waters.

According to a 1997 survey of county health officials (Taylor et al., 1997), the percentage of failing septic systems in each county (including illegally connected to tile drains and ditches) ranged from 15% to as high as 75%. There are also many older homes in rural areas where septic systems were constructed without appropriately sized leach fields.

The number of failing septic systems in each of the four watersheds was calculated using a Geographic Information Systems (GIS) methodology, which starts with the Indiana State Census 2000 Blockgroup Population Density layer acquired from IGS (U.S. Census Bureau, 2000a). Figures 4-12 through 4-15 show this population density information for each of the four watersheds. Using the population density, best professional judgment (BPJ) estimates were made that: (a) within rural areas (i.e. population density < 260/km^2), 100% of sewage disposal is via septic system, and (b) within urban and suburban areas (i.e. density > 260/km^2), 10% of sewage disposal is via septic system, with the remainder of the population served by municipal sewers.

Once the population served by septic systems was established, the *E. coli* load from these systems was estimated, assuming a 50% septic system failure rate, a standard wastewater production rated of 75 gallons/day per person (Geldreich, 1978), and a typical domestic sewage *E. coli* concentration of 1.07 x 10^6 counts/100 mL (IDEM, 2003 and IDEM, 2003a).

The 50% assumed septic system failure rate is higher than average failure rates from other TMDL studies, but is a relative midpoint from the Taylor, et al (1997) study. One other factor that is often considered for estimation of *E. coli* loads from septic systems is the systems' proximity to receiving waters. This is considered since sewage from a failed system will generally experience additional decay as it travels through additional soils or over land before entering a receiving stream. However, given the prevalence of tile drains in these watersheds and their performance as a conduit for failed septic loads, the proximity to receiving water factor was omitted from this analysis. As such, the calculated value represents the total potential conservative *E. coli* load from failing septic systems. Table 4-6 shows the calculated total septic loads for each of the four watersheds.

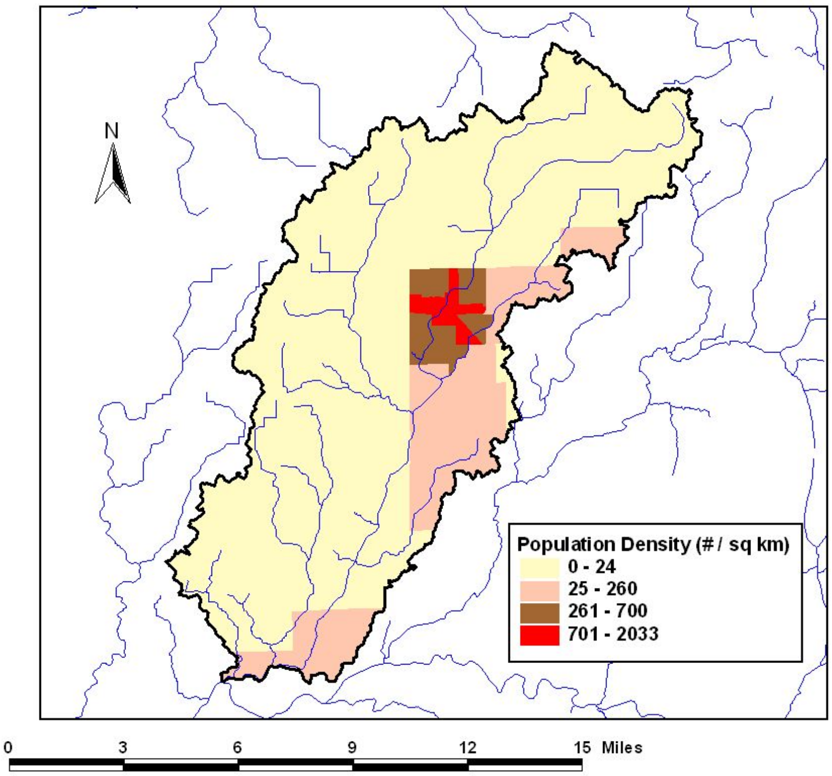

Figure 4-12. U.S. 2000 Census Population Densities in the Duck Creek Watershed

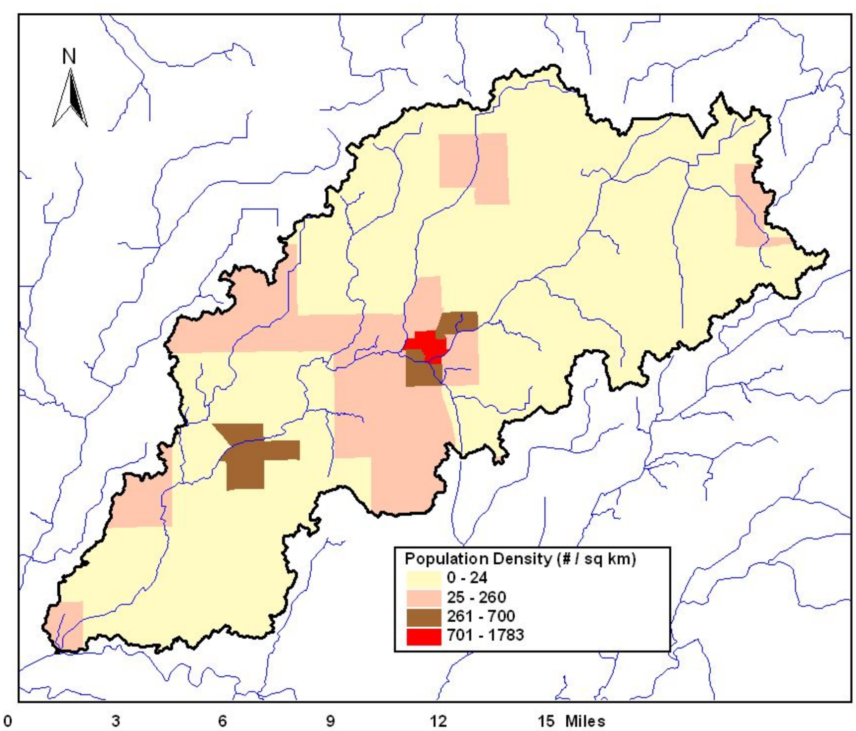

Figure 4-13. U.S. 2000 Census Population Densities in the Pipe Creek Watershed

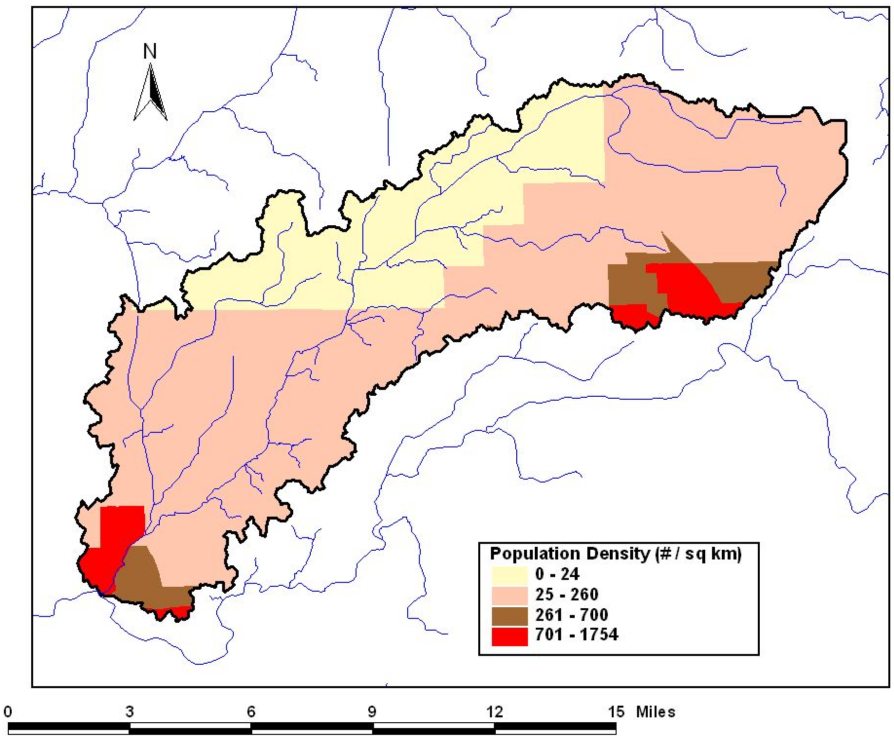

Figure 4-14. U.S. 2000 Census Population Densities in the Killbuck Creek Watershed

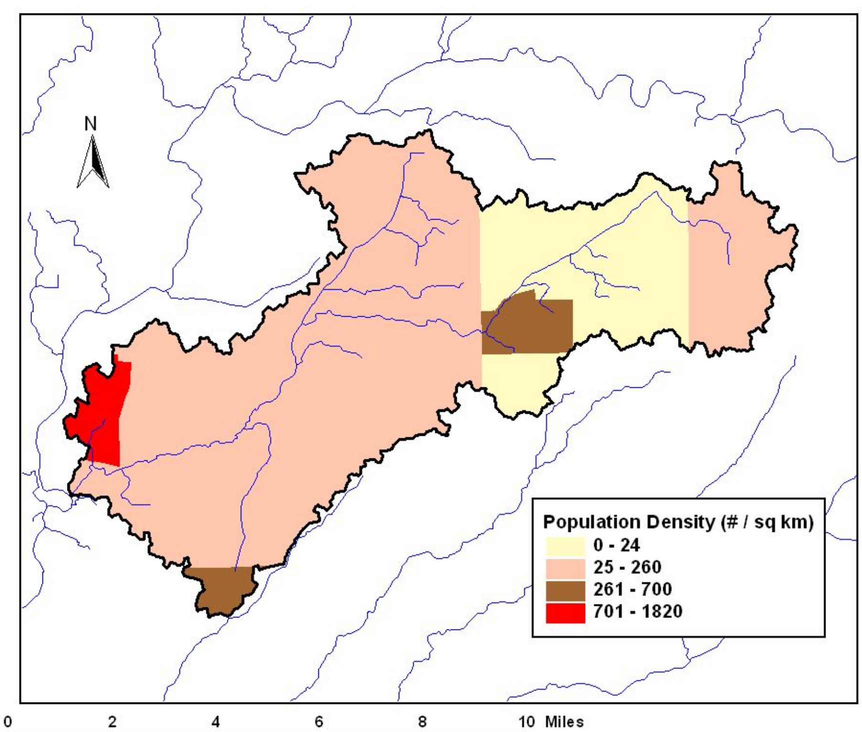

Figure 4-15. U.S. 2000 Census Population Densities in the Stony Creek Watershed

Table 4-6. Total Potential Septic, Wildlife, and Domestic Pet *E. coli* Loads for the Duck Creek, Pipe Creek, Killbuck Creek, and Stony Creek Watersheds

Watershed	Total Potential E. Coli Load (count/day)		
	Failing Septic Systems	Wildlife	Domestic Pets
Duck Creek	6.28E+12	1.32E+13	4.48E+12
Pipe Creek	1.82E+13	2.00E+13	6.44E+12
Killbuck Creek	2.44E+13	1.39E+13	8.66E+12
Stony Creek	9.67E+12	7.15E+12	4.73E+12

4.2.2 AGRICULTURE

For nonpoint sources involving agricultural activities, potential sources include the application of agricultural manure to row crop and pasture lands and the deposition of manure onto pasture lands from free-ranging livestock.

4.2.2.1 Land Application of Agricultural Manure

Processed agricultural manure from CAFOs, CFOs, and smaller operations is generally collected in waste lagoons and applied to land surfaces from late spring to early fall. Because a high percentage of lands surrounding the impaired waters in the four watersheds are utilized for row crops and grazing, loading from these areas must be considered. In areas where manure is applied to cropland and pasture, *E. coli* rates from livestock are calculated based on manure application rates and literature values for bacteria counts in manure from different livestock sources. Manure application rates from different animal sources can vary according to management practices.

For the Duck Creek, Pipe Creek, Killbuck Creek, and Stony Creek watersheds, estimates of the cow, pig, and sheep populations in the watershed were calculated using the total numbers of cows, pigs, and sheep in Delaware, Madison, Hamilton, and Tipton counties (Table 4-7, USDA (2002)) and a GIS analysis to determine the percentage of each county included in the four watershed study area (Table 4-8). Table 4-9 shows the resultant estimates of farm animals in the study area portions of Delaware, Madison, Hamilton, and Tipton counties.

Using the assumption that 90% of all manure generated by these animals (including CAFOs and CFOs) is collected and then intentionally applied to row crop and pasture lands, *E. coli* loads were estimated based on the *E. coli* loading rates in Table 4-4 and the percentage of total county row crop and pasture acreage occurring within each watershed. These calculated loads represent the total potential conservative *E. coli* load from manure land application activities. As will be discussed in Section 5, these estimated *E. coli* loads were further distributed to the subwatersheds within each watershed, again, based on the percentage of total county row crop and pasture acreage occurring within each subwatershed.

Table 4-7. USDA Cow, Pig, and Sheep Populations in Delaware, Hamilton, Madison, and Tipton Counties [USDA (2002) except where noted]

County	Beef	Milk	Other	Total	Swine	Sheep
Delaware	1,300	358	2,184	3,842	22,691	601
Hamilton	1,268	302	2,346	3,916	**24,045**	988
Madison	1,730	154	2,456	4,340	26,875	655
Tipton	239*	60*	1,349	1,648	42,889	629

Numbers in **BOLD** from USDA (1997); * estimated from other counties

Table 4-8. Calculated Percentages of Each County within the Duck Creek, Pipe Creek, Killbuck Creek, and Stony Creek Watersheds

Acreage	County	Study Area	% in Area
Delaware	253,212	57,647	22.77%
Hamilton	257,348	42,398	16.47%
Madison	289,734	148,260	51.17%
Tipton	166,592	18,733	11.24%

Table 4-9. Estimates of Cow, Pig, and Sheep Populations within the Duck Creek, Pipe Creek, Killbuck Creek, and Stony Creek Portions of Delaware, Hamilton, Madison, and Tipton Counties

County	Beef	Milk	Other	Total	Swine	Sheep
Delaware	296	82	497	875	5,166	137
Hamilton	209	50	387	645	3,961	163
Madison	885	79	1,257	2,221	13,752	335
Tipton	27	7	152	185	4,823	71

4.2.2.2 Direct Deposition of Manure onto Pasture Lands

Fecal matter from livestock can be deposited directly to the stream in instances where livestock have stream access, or the fecal matter can be transported to the stream in runoff from grazing or pasture lands. Beef, dairy cattle, and sheep deposit feces onto the grazing pastureland. During a precipitation event, fecal material containing *E. coli* is transported to the streams. Figures 2-10 through 2-13 show the land uses associated with each watershed. While the majority of land in each of the four watersheds is in row crops, there are also smaller patches of land area associated with a grazing/pasture use. These pasture areas are commonly adjacent to tributaries of Duck Creek, Killbuck Creek, Pipe Creek, and Stony Creek.

Although the pasture land areas may seem relatively small compared to the lands with row crops, unconfined animals often have direct access to streams that pass through the pastures. Bacteria in feces deposited by grazing animals in streams is not subject to the higher desiccation and die-off rates of that deposited on land, and therefore can constitute an immediate water quality concern.

In Hamilton County's recent study of the Stony Creek watershed, staff noted cattle access to stream and trampling of riparian vegetation by cattle from pasture areas adjacent to the waterbody (Baker and Nelson, 2004).

For the Duck Creek, Pipe Creek, Killbuck Creek, and Stony Creek watersheds, estimates of the free-ranging animal populations in the watershed were calculated by subtracting the CAFO/CFO populations in Table 4-5 from the total numbers estimated in Table 4-9. Table 4-10 shows the resultant estimates of farm animals in the study area that are not associated with CAFOs/CFOs.

Using the assumption that 10% of all manure generated by these animals is deposited directly onto pasture lands or into streams, *E. coli* loads were estimated based on the *E. coli* loading rates in Table 4-4 and the percentage of total county pasture acreage occurring within each watershed. These calculated loads represent the total potential conservative *E. coli* load from direct deposition of manure. As will be discussed in Section 5, these estimated *E. coli* loads were further distributed to the subwatersheds within each watershed, again, based on the percentage of total county pasture acreage occurring within each subwatershed. Section 5 also discusses system attenuation of the estimated loads.

Table 4-10. Estimates of Non-CAFO, Non-CFO Related Cow, Pig and Sheep Populations within the Duck Creek, Pipe Creek, Killbuck Creek, and Stony Creek Portions of Delaware, Hamilton, Madison, and Tipton Counties

County	Beef	Milk	Other	Total	Swine	Sheep
Delaware	296	82	497	875	1,602	137
Hamilton	209	50	387	645	545	163
Madison	268	0	136	404	4,444	335
Tipton	27	7	152	185	3,303	71

4.2.3 WILDLIFE

As for free-ranging livestock, fecal matter from wildlife can be deposited directly to the stream, or it can be transported to the stream in surface runoff from woods, pastureland, and cropland. Direct deposition to streams varies with species. For example, beaver spend the majority of their time in water, so it would be assumed that most of their fecal matter would be directly deposited to the stream.

According to personnel from Indiana Department of Natural Resources (IDNR) District 11 (includes Delaware County), the predominant wildlife species in the study area are deer, raccoon, and Canadian geese (Hanauer, 2005). Estimated populations for these species were determined assuming that all land use categories within the watersheds are accessible to the species and then by estimating the population density (animals/acre) of each species.

For deer, the IDNR is hesitant to provide population or density estimates for the species, although the number of deer/automobile collisions per billion miles traveled in Indiana are available for 1991-2003 via IDNR Deer Harvest Summaries (IDNR, 1999 – 2003). This statistic is used by IDNR as an index of deer population trends. According to McCreedy (1995) the Indiana deer population in 1991 was approximately 350,000. Using this number, the numbers of deer harvested each year between 1991-2003, the number of deer/automobile collisions that occurred each year between 1991-2003, and an assumption that one third of the deer herd is reproduced each year, estimates of the Indiana deer population were made for each of the years between 1991-2003. The estimated average annual deer population over that period is 383,359, or 0.0175 deer/acre.

The raccoon population density was determined in a similar fashion. IDNR reports that raccoon densities in Indiana can vary between 1 animal/acre and 1 animal/40 acres (IDNR, 2005). IDNR also uses road kill surveys for a relative index of raccoon population trends in the state.

According to these surveys, the relative index for north central Indiana has been the highest in the state for the last two years (Plowman (2003) and Plowman (2004)). A ranking of the reported indices for 2002, 2003, and March 2004 shows the average index for north central Indiana to be 64.5. By fitting this relative ranking into a distribution between 1/acre and 1/40 acres, an estimate of one raccoon / 14.2 acres (or 0.07 / acre) is estimated for north central Indiana.

According to the IDNR Water Fowl Research Biologist, indices for Canadian geese population estimates in 2001-2004 have led to statewide population estimates between 80,200 and 121,054 birds (McNew, 2005). The average estimate over that time frame is 98,965 birds, or 0.0042 / acre.

Animal fecal coliform loading rates for geese, deer, and raccoon were acquired from the USEPA Bacteria Indicator Tool documentation (USEPA, 2000). Using a 0.9 multiplier to convert between fecal coliform and *E. coli*, along with the above estimates for deer, raccoon, and Canadian geese population densities in the study area, areal *E. coli* loading rates can be calculated for each species. Table 4-11 shows the animal loading rates, population densities, areal loading rates, and the resultant watershed loads for these calculations. Table 4-6 show the total estimated wildlife *E. coli* loads for each of the four watersheds.

Table 4-11. Estimates of North Central Indiana *E. coli* Areal Loading Rates for Canadian Geese, Deer, and Raccoon

Species	Fecal Coliform Loading Rate[a] (#/animal-day)	E. Coli Loading Rate (#/animal-day)	Animal Density[b] (#/acre)	E. Coli Areal Loading Rate (#/acre-day)	Duck Creek E. Coli Loads (#/day)	Pipe Creek E. Coli Loads (#/day)	Killbuck Creek E. Coli Loads (#/day)	Stony Creek E. Coli Loads (#/day)
Goose	4.90E+10	4.41E+10	0.0042	1.85E+08	1.21E+13	1.84E+13	1.23E+13	6.59E+12
Deer	5.00E+08	4.50E+08	0.0175	7.88E+06	5.15E+11	7.84E+11	5.25E+11	2.80E+11
Raccoon	1.25E+08	1.13E+08	0.07	7.88E+06	5.15E+11	7.84E+11	5.25E+11	2.80E+11
			totals	2.01E+08	1.32E+13	2.00E+13	1.34E+13	7.15E+12

[a] USEPA Bacteria Indicator Tool (2000); [b] various IDNR sources (1999-2003)

4.2.4 DOMESTIC PETS

Cats and dogs can also be potential sources of *E. coli* within a watershed. As with wildlife, fecal matter deposited by domestic animals can accumulate and wash off during wet weather events. The domestic animals source category is expected to be much more significant in urban and suburban areas, where greater densities of pets are typically found.

Estimates for *E. coli* loadings attributable to domestic pets was performed using a GIS analysis.

The analysis started with the US Census 2000 Blockgroups data layer, which includes a value for the number of households within each blockgroup. The blockgroup data layer was then intersected with the subwatershed boundary layer for the Duck Creek, Pipe Creek, Killbuck Creek, and Stony Creek watersheds in order to establish the number of households within each subwatershed.

According to the American Veterinary Medical Association (AVMA, 2002), 36.1% of households own at least one dog and the national average number of dogs per dog-owning household is 1.6. Three studies referenced by the USEPA stormwater Best Management Practices website (HGIC (1996), Hardwick (1997), and Swann (1999)) indicate that an average of 36.7% of dog owners never or rarely clean up after their dogs. The GIS product of: (a) the number of households, (b) the percentage of households owning dogs, (c) the number of dogs per dog-owning household, and (d) the percentage of dog owners that rarely or never clean up after their dogs, produces the number of dogs within each subwatershed that contribute *E. coli* loadings. Using the USEPA Bacteria Indicator Tool (2000) fecal coliform loading rate value for dogs (4.09×10^9 counts/day) and a 0.9 conversion factor for fecal coliform to *E. coli*, the total potential conservative *E. coli* load associated with dogs is calculated within the GIS for each subwatershed.

The AVMA study also shows that 31.6% of households own at least one cat and the national average number of cats per cat-owning household is 2.1. The Rouge River Bird Observatory at the University of Michigan-Dearborn reports that approximately 50% of all cats are outdoor cats (UMD-RRO, 2003). The GIS product of: (a) the number of households, (b) the percentage of households owning cats, (c) the number of cats per cat-owning household, and (d) the percentage of outdoor cats, produces the number of cats within each subwatershed that contribute *E. coli* loadings. Using a feline fecal coliform loading rate value from Virginia's Accotink Creek fecal coliform TMDL (2.682×10^8 counts/day, (VDEQ, 2002)) and a 0.9 conversion factor for *E. coli*, the total potential conservative *E. coli* load associated with cats is calculated within the GIS for each subwatershed. Table 4-6 shows the total estimated domestic pet *E. coli* loads for each of the four watersheds.

5.0 TECHNICAL APPROACH

The technical approach applied for the Duck Creek, Pipe Creek, Killbuck Creek, and Stony Creek TMDLs employed an incremental watershed adaptation of the Load Duration Curve (LDC) methodology. This section describes the process associated with the incremental watershed LDC methodology.

The Load Duration Curve (LDC) approach toward TMDLs is quickly becoming the method of choice in bacterial TMDL development for states that are required to address water quality impairments in a quick and efficient manner. The LDC approach is based on a cumulative frequency distribution of flow information (or a Flow Duration Curve – QDC) for a specific monitoring location. The multiplicative product of the QDC and the numeric water quality concentration criterion for the parameter of interest is a cumulative frequency distribution of pollutant loads, or LDC (Stiles and Cleland, 2003).

Use of the QDC obviates the need to determine a design storm or selected flow recurrence interval with which to characterize the appropriate flow level for the assessment of critical conditions. That approach was flawed in its pursuit of a single critical condition, especially for impaired water bodies impacted by both point and nonpoint sources. The LDC approach also recognizes that a water body's capacity to assimilate pollutant loads is dependent upon the volume of water entering the system, as well as the mass of pollutant coming in.

Figure 5-1 shows the QDC for USGS flow gage 03348350 on Pipe Creek near Frankton. The period of record for this gage runs from May 1968 to the present. QDC plots are created by ranking the observed flows from highest to lowest and then establishing, for each flow value, the percentage of time that the flow record exceeds it. The dependent y-axis of the QDC is typically displayed in a logarithmic scale, since high flow events would otherwise overwhelm the median and low flows (Stiles, 2001).

A LDC is created by taking the product of the appropriate water quality standard concentration and the QDC distribution. For *E. coli* bacteria in Indiana, two numerical water quality standards exist: (a) a chronic, or geometric mean, standard of 125 colonies/100 mL, based on 5 samples taken at equal intervals over 30 days, and (b) an acute, or never-to-exceed, standard of 235 colonies/100 mL. Figures 5-2 and 5-3 show the corresponding LDCs for each of these standards at the Pipe Creek USGS gage. These figures also include monitoring data plotted on the LDCs. Each observed load is calculated as the product of the measured concentration and the observed flow. The calculated load is then plotted on the LDC at the percentile value corresponding to the observed flow.

As can be seen from Figures 5-2 and 5-3, the observed *E. coli* loads for the Pipe Creek gage location typically fall above the LDCs. This indicates impairment of the stream. In the case of Pipe Creek, the observed loads can exceed the LDC by more than an order of magnitude. In order to bring observed loads down to within water quality standards, the required load reductions will necessarily exceed 90%.

As can also be seen from Figure 5-2, the number of observed geometric mean loads is limited by the availability of monitoring data. In accordance with Indiana Administrative Code Title 327, Article 2, Section 1-6(d), five samples, collected at equally spaced intervals over a 30 day period, are required in order to derive a geometric mean of the observations with which to compare to the geometric mean standard of 125 colonies / 100 mL. For the Pipe Creek example in Figure 5-2, just five samples collected in 2001 meet that criterion. However, many of the monitoring locations in the four watersheds have 4 or less single samples. For this reason, only the single sample "never-to-exceed" standard of 235 colonies / 100 mL was used to determine the loading reductions required.

Advantages of the LDC approach include quick and efficient implementation, ease of graphical presentation and load reduction analysis, and quick assessment of loading conditions for various key recurrence intervals of flow. Disadvantages include the need for corresponding flow information with every water quality sample, and the associated difficulty in assessing the relative loading contributions from various source categories. Finally, since the LDC approach does not involve explicit computational modeling, the concept of establishing a post-implementation TMDL scenario to assess the effects of load reducing management practices is not supported.

In order to address some of the above disadvantages, the incremental watershed LDC approach was employed. The incremental watershed LDC approach uses watershed information such as the drainage areas to each water quality monitoring location, and the distribution of land uses, soil hydrologic groups, and known management practices applied to specific land parcels, in order to estimate QDCs for all sampling locations within a watershed. Once subwatersheds based on sampling location have been established and QDCs determined for each of them, estimates of pollutant loadings are determined for each subwatershed, based on GIS point location data, GIS distributed surface characterization data, and literature. The subwatershed loading estimates are then adjusted to match the median loads of the load duration curves for the highest observed concentration at each sampling point. Finally, percent reductions for each of the source categories contributing to the subwatershed loads are increased until water quality standards are achieved for all subwatersheds. The remainder of this section provides more detail on the incremental watershed LDC approach.

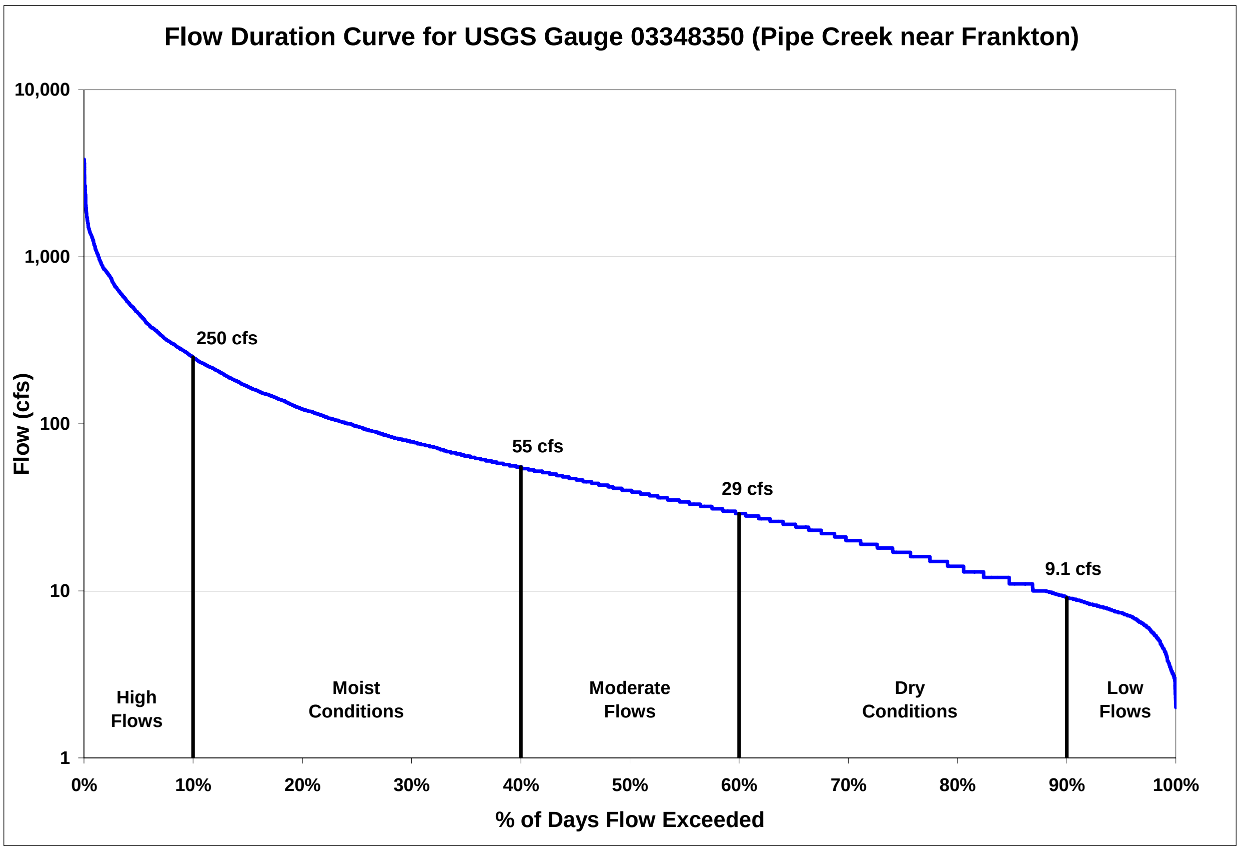

Figure 5-1. Flow Duration Curve for Pipe Creek Gage (5/1968 – 9/2003)

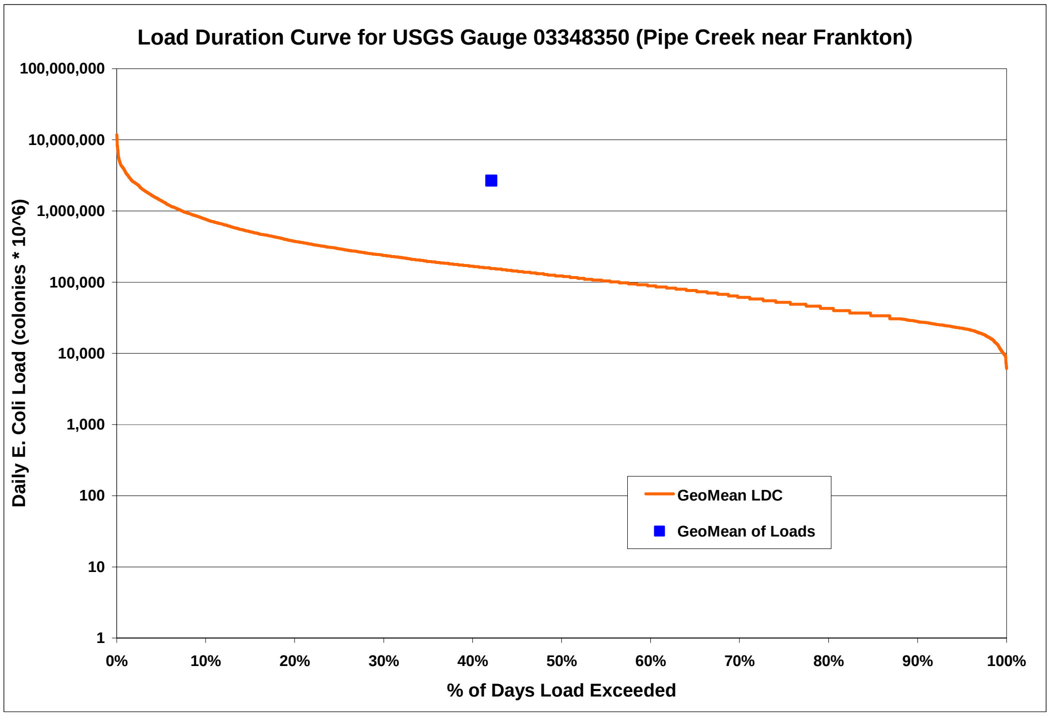

Figure 5-2. Geometric Mean Load Duration Curve for Pipe Creek Gage (5/1968 – 9/2003)

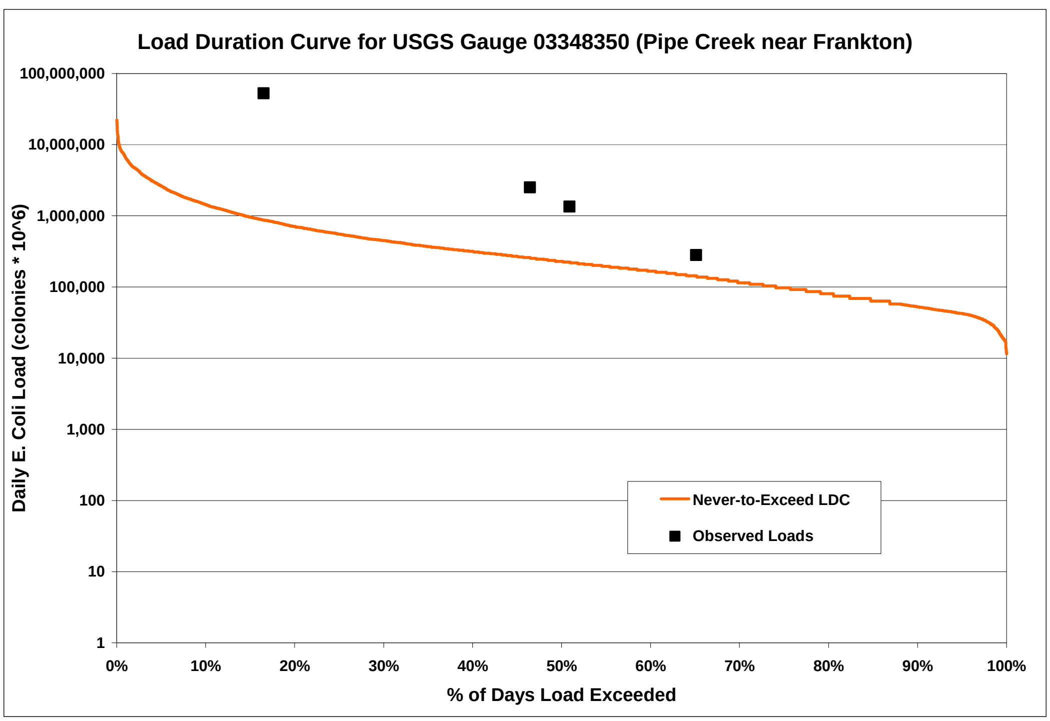

Figure 5-3. “Never-to-Exceed” Load Duration Curve for Pipe Creek Gage (5/1968 – 9/2003)

5.1 SUBWATERSHED SEGMENTATION

The first step in the incremental watershed LDC approach is to establish accurate subwatershed boundaries that correspond to the sampling locations within the watershed. Care must be taken to ensure that the subwatershed boundaries are hydrologically consistent with known stream networks and topographical elevation data. As discussed in Section 2, the SRTM elevation data was used as the basis for delineating the subwatershed boundaries. Stream features from the NHD 1:100,000-scale hydrography network (with additional reaches extracted from digital raster graphic quad maps) were etched into the SRTM grids, using digital integration techniques developed by Saunders (2000) and Hellweger (1997). The resultant subwatershed delineations are shown in Figures 5-4 through 5-7. Each subwatershed is denoted by the Station ID of the sampling location at its outlet. Subwatersheds are classified as either "headwater" or "incremental" subwatersheds, based on whether the specific subwatershed receives any upstream flow. The Duck Creek and Pipe Creek watersheds also include an "unmonitored" subwatershed, which defines an area within the drainage area to the impaired water that is also downstream of all sampling locations. Tables 5-1 through 5-4 show the acreages associated with each subwatershed. As with the figures, headwater subwatersheds are marked in yellow.

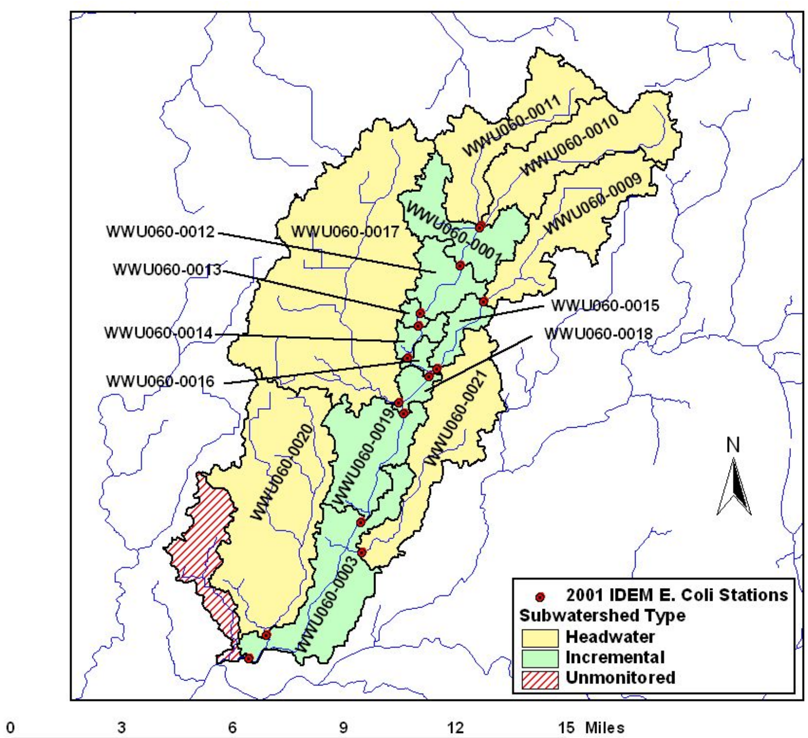

Figure 5-4. Subwatersheds Delineated for the Duck Creek Watershed

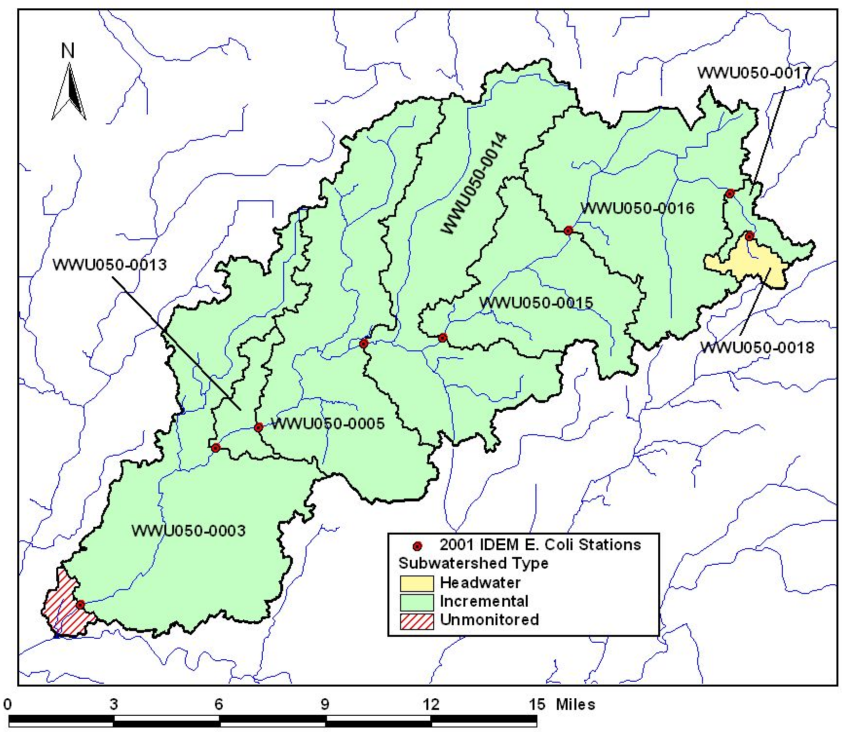

Figure 5-5. Subwatersheds Delineated for the Pipe Creek Watershed

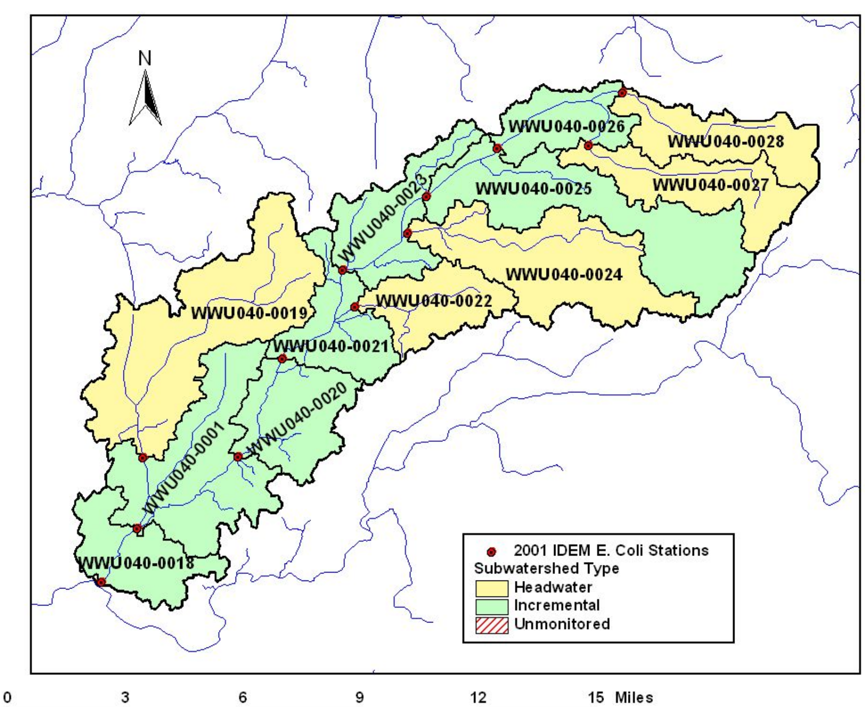

Figure 5-6. Subwatersheds Delineated for the Killbuck Creek Watershed

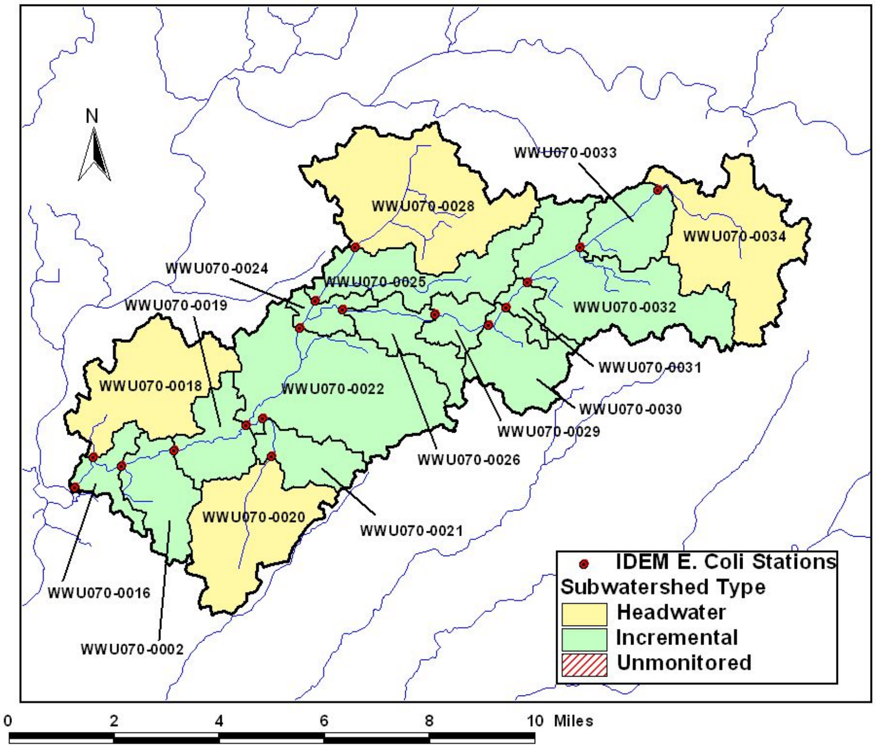

Figure 5-7. Subwatersheds Delineated for the Stony Creek Watershed

Table 5-1. Subwatershed Statistics for the Duck Creek Watershed

Duck Creek Monitoring Location	Station ID	Subwatershed Area (acres)	Cumulative Area (acres)	Cumulative Drainage Area Ratio to USGS Gage*	Drainage Area Ratio Median Flow (cfs)
CR 1400N	WWU060-0010	5,277	5,277	0.074	2.95
Todd Ditch	WWU060-0011	4,827	4,827	0.067	2.70
CR 1300N	WWU060-0001	3,021	13,125	0.183	7.34
S 9th Street	WWU060-0012	1,683	14,808	0.207	8.28
Elwood WWTP	WWU060-0013	259	15,067	0.211	8.42
CR 1050N	WWU060-0014	562	15,629	0.218	8.74
LDC - Hwy 28	WWU060-0009	5,001	5,001	0.070	2.80
LDC - CR 900W	WWU060-0015	979	5,980	0.084	3.34
CR 1000N	WWU060-0016	347	21,956	0.307	12.28
Polywag Creek	WWU060-0017	16,168	16,168	0.226	9.04
CR 900N	WWU060-0018	593	38,717	0.541	21.65
Hayworth Road	WWU060-0019	3,591	42,308	0.591	23.65
Bear Creek	WWU060-0020	10,184	10,184	0.142	5.69
Lamberson Ditch	WWU060-0021	5,296	5,296	0.074	2.96
SR 213	WWU060-0003	4,990	62,778	0.877	35.10
Unmonitored	-----------	2,671	65,449	0.915	36.59

*compared to USGS gage 03348350 (Pipe Creek near Frankton)

Table 5-2. Subwatershed Statistics for the Pipe Creek Watershed

Pipe Creek Monitoring Location	Station ID	Subwatershed Area (acres)	Cumulative Area (acres)	Cumulative Drainage Area Ratio to USGS Gage*	Drainage Area Ratio Median Flow (cfs)
CR 600W	WWU050-0018	1,208	1,208	0.017	0.68
CR 900N	WWU050-0017	1,546	2,754	0.038	1.54
CR 1400N	WWU050-0016	17,747	20,501	0.287	11.46
CR 1100N	WWU050-0015	11,297	31,798	0.444	17.78
CR 200W	WWU050-0014	20,127	51,925	0.726	29.03
CR 500W	WWU050-0005	19,620	71,544	1.000	40.00
SR 128	WWU050-0013	2,291	73,835	1.032	41.28
SR13	WWU050-0003	24,651	98,486	1.377	55.06
Unmonitored	-------	1,019	99,504	1.391	55.63

*compared to USGS gage 03348350 (Pipe Creek near Frankton)

Table 5-3. Subwatershed Statistics for the Killbuck Creek Watershed

Killbuck Creek Monitoring Location	Station ID	Subwatershed Area (acres)	Cumulative Area (acres)	Cumulative Drainage Area Ratio to USGS Gage*	Drainage Area Ratio Median Flow (cfs)
Mud Creek	WWU040-0028	4198	4198	0.207	2.48
Killbuck Headwaters	WWU040-0027	4621	4621	0.228	2.73
SR28/US 35	WWU040-0026	3057	11876	0.586	7.03
CR 700W	WWU040-0025	8739	20615	1.016	12.20
CR 750W	WWU040-0024	7748	7748	0.382	4.58
NCR 925W	WWU040-0023	4204	32567	1.606	19.27
SR 332	WWU040-0022	3456	3456	0.170	2.04
CR 425E	WWU040-0021	3727	39750	1.960	23.52
CR 400N	WWU040-0020	4304	44054	2.172	26.06
Liitle Killbuck Creek	WWU040-0019	10991	10991	0.542	6.50
SR 9 Bridge	WWU040-0001	7812	62857	3.099	37.19
Broadway St.	WWU040-0018	3730	66587	3.283	39.40

*compared to USGS Gage 03348020 near Gaston

Table 5-4. Subwatershed Statistics for the Stony Creek Watershed

Stony Creek Monitoring Location	Station ID	Subwatershed Area (acres)	Cumulative Area (acres)	Cumulative Drainage Area Ratio to USGS Gage*	Drainage Area Ratio Median Flow (cfs)
CR 650 W	WWU070-0034	3660	3660	0.115	2.65
CR 825 W	WWU070-0033	1362	5023	0.158	3.63
CR 925 W	WWU070-0032	3910	8933	0.281	6.46
SR 132/13	WWU070-0031	386	9319	0.293	6.74
CR 1000 W	WWU070-0030	1628	10947	0.344	7.92
Cyntheanne Rd	WWU070-0029	679	11627	0.366	8.41
No description	WWU070-0026	1151	12778	0.402	9.24
E 206th St / Durbin Rd	WWU070-0028	4580	4580	0.144	3.31
E 196th St / Mystic Rd	WWU070-0025	2160	6740	0.212	4.88
E 196th St / Mystic Rd	WWU070-0024	582	20099	0.632	14.54
166th St.	WWU070-0020	2998	2998	0.094	2.17
private dr off SR 38	WWU070-0021	1059	4057	0.128	2.93
SR 38	WWU070-0022	4860	29016	0.913	20.99
Union Chapel Rd	WWU070-0019	1309	30325	0.954	21.94
Cumberland Rd Gage	WWU070-0002	1467	31792	1.000	23.00
166th St. Noblesville	WWU070-0018	3059	3059	0.096	2.21
Allisonville Rd.	WWU070-0016	723	35573	1.119	25.74

* compared to USGS Gage 03350700 near Noblesville

5.2 ESTABLISHMENT OF QDCS AND DETERMINATION OF ALLOWABLE LDCS

In order to apply the LDC methodology to every monitoring location in the Duck Creek, Pipe Creek, Killbuck Creek, and Stony Creek watersheds, flow information must be derived for each location. USGS gaged flows within these watersheds are used as the basis to determine flows at the other locations. In the Pipe Creek watershed, USGS gage 03348350 is located at County Road 500W. In the Stony Creek watershed, USGS gage 03350700 is located in Noblesville at Allisonville Road. In the Killbuck Creek watershed, the currently inactive USGS gage 03348020 was located near Gaston just upstream of County Road 700W**.** No USGS gage or flow history exists for Duck Creek, so the gage from the adjacent Pipe Creek watershed was used as a surrogate. Drainage area ratios for all monitoring locations in the watersheds were established by dividing the cumulative watershed area for the location by the cumulative watershed area at the USGS gage. Tables 5-1 through 5-4 show the drainage area ratios and median flows for each monitoring location.

Using the drainage area ratios and the QDC for each USGS gage location, an initial set of QDCs for the other watershed monitoring locations can be created by multiplying each location's drainage area ratio by the USGS gage QDC. The QDCs were further adjusted by considering the land uses, soil type hydrologic groups, and the row crop tile drainage locations in each subwatershed.   These GIS layers are shown in Section 2. Using the intersection of these GIS distributions, the Soil Conservation Service (SCS) Curve Number (CN) methodology (USDA-SCS, 1973) was applied to establish estimated CNs for each intersected parcel. Table 5-5 shows the CNs assigned to each parcel of a specific land use/hydrologic group combination. For row crop land uses that also have a drainage classification of “somewhat poorly drained”, “poorly drained”, or “very poorly drained”, tile drainage was assumed to have been implemented, thereby reducing the CN by an additional 10 units (i.e. 10%).

Using GIS, a “composite curve number” for the total area draining to a USGS gage was determined. This composite CN is calculated within the GIS by determining the percentage of each land use/hydrologic group/row crop drainage combination occurring within the drainage area, multiplying the individual percentages by the CN associated with each combination, and then summing the resultant products. This process is illustrated for USGS gage 03348350 at Pipe Creek in Table 5-6. The composite CN for that gage is 79.19.

The same approach for determining composite curve numbers is then followed for each subwatershed in the study area. As an example of this process, Tables 5-7, 5-8, and 5-9 show the respective areas, percentages of subwatershed areas, and incremental curve numbers, for each land use/hydrologic group/tile drainage combination in the Pipe Creek subwatersheds. Table 5-9 also shows the composite curve number for each Pipe Creek subwatershed, as well as a calculated “Composite Curve Number ratio” of the subwatershed composite curve number to the USGS gage composite curve number. This composite CN ratio is used as a multiplicative factor and applied to the incremental flows for each subwatershed. Figures 5-8 through 5-11 show the resultant QDCs for all monitoring locations within the watersheds. Tables 5-10 through 5-13 show the CN-adjusted median flows associated with each QDC.

As can be seen from the Tables 5-10 through 5-13, the adjustments to the QDC profiles are relatively insignificant. This is partly due to the magnitudes the SCS Curve Numbers specified for each category and also due to the relatively minor differences specified for tile drainage management practices on agricultural row crops. Other management practices may also affect the QDC profile, but additional flow adjustments will probably remain minor in comparison to the drainage area ratio factor.

Once the QDCs for each monitoring location are established, duration curves for the allowable *E. coli* loads are easily calculated by multiplying the QDC distribution by the appropriate water quality criterion. Individual "never-to-exceed" LDC plots for all monitoring locations within the watersheds are included in Appendix C. These LDCs represent the product of the individual QDCs and the water quality standard of 235 colonies / 100 mL.

Table 5-5. SCS Curve Numbers Assigned to Land Use/Hydrologic Group/Tile Drainage Categories

NLCD Land Use Category	Hydrologic Soil Group		
	B	C	D
Open Water	100	100	100
Low Intensity Residential	68	79	84
High Intensity Residential	85	90	92
Commercial/Industrial/Transportation	90	92	94
Deciduous Forest	55	70	77
Evergreen Forest	55	70	77
Mixed Forest	55	70	77
Pasture/Hay	61	74	80
Row Crops - no conservation treatment	81	88	91
Row Crops - tile drainage	71	78	81
Urban/Recreational/Grasses	65	77	82
Woody Wetlands	95	95	95
Emergent Herbaceous Wetlands	95	95	95

(Source, USDA-SCS (1973))

Table 5-6. Composite Curve Number Process for Pipe Creek Gage Drainage Area

NLCD Land Use (MRLC) and NRCS Soil Hydrologic Group (Statsgo)	Pipe Creek Gage Area (acres)	Pipe Creek Gage Percent	SCS CN	Composite CN
Open Water - B,C,D	172	0.24%	100	0.24
Low Intensity Residential - B	805	1.12%	68	0.76
Low Intensity Residential - C	953	1.33%	79	1.05
Low Intensity Residential - D	0	0.00%	84	0.00
High Intensity Residential - B	78	0.11%	85	0.09
High Intensity Residential - C	36	0.05%	90	0.05
High Intensity Residential - D	0	0.00%	92	0.00
Commercial/Industrial/Transportation - B	249	0.35%	90	0.31
Commercial/Industrial/Transportation - C	114	0.16%	92	0.15
Commercial/Industrial/Transportation - D	0	0.00%	94	0.00
Deciduous Forest - B	733	1.02%	55	0.56
Deciduous Forest - C	1,416	1.98%	70	1.39
Deciduous Forest - D	0	0.00%	77	0.00
Evergreen Forest - B	1	0.00%	55	0.00
Evergreen Forest - C	1	0.00%	70	0.00
Evergreen Forest - D	0	0.00%	77	0.00
Mixed Forest - B	0.4	0.00%	55	0.00
Mixed Forest - C	0.2	0.00%	70	0.00
Mixed Forest - D	0	0.00%	77	0.00
Pasture/Hay - B	1,923	2.69%	61	1.64
Pasture/Hay - C	6,369	8.90%	74	6.59
Pasture/Hay - D	0	0.00%	80	0.00
Row Crops - B, no tile drainage	4,278	5.98%	81	4.84
Row Crops - B, tile drained	0	0.00%	71	0.00
Row Crops - C, no tile drainage	13,937	19.48%	88	17.14
Row Crops - C, tile drained	38,479	53.78%	78	41.95
Urban/Recreational/Grasses - B	206	0.29%	65	0.19
Urban/Recreational/Grasses - C	579	0.81%	77	0.62
Urban/Recreational/Grasses - D	0	0.00%	82	0.00
Woody Wetlands - B,C,D	1,155	1.61%	95	1.53
Emergent Herbaceous Wetlands - B,C,D	59	0.08%	95	0.08
Totals	71,544	100.0%		79.19

Table 5-7. Pipe Creek Subwatershed Land Use/Hydrologic Group/Tile Drainage Areas

NLCD Land Use (MRLC) and NRCS Soil Hydrologic Group (Statsgo)	CR-600W acres	CR-900N acres	CR-1400N acres	CR-1100N acres	CR-200W acres	CR-500W acres	SR-128 acres	SR-13 acres	Ungaged acres
Open Water - B,C,D	0.2	0.2	46	10.1	38	77	-----	19.7	0.7
Low Intensity Residential - B	-----	-----	-----	176	556	72	235	105	8.3
Low Intensity Residential - C	-----	143	5.9	180	542	82	77	70	-----
Low Intensity Residential - D	-----	-----	-----	-----	-----	-----	-----	-----	-----
High Intensity Residential - B	-----	-----	-----	6.2	61	11.0	14.7	0.6	-----
High Intensity Residential - C	-----	2.6	0.2	6.9	20	6.5	0.3	1.4	-----
High Intensity Residential - D	-----	-----	-----	-----	-----	-----	-----	-----	-----
Commercial/Industrial/Transportation - B	-----	-----	-----	13.4	222	14.0	51	-----	-----
Commercial/Industrial/Transportation - C	-----	24	28	18.6	36	7.2	-----	18.0	-----
Commercial/Industrial/Transportation - D	-----	-----	-----	-----	-----	-----	-----	-----	-----
Deciduous Forest - B	-----	-----	-----	6.5	179	548	55	437	28
Deciduous Forest - C	46	34	273	455	421	187	0.8	155	3.5
Deciduous Forest - D	-----	-----	-----	-----	-----	-----	-----	-----	-----
Evergreen Forest - B	-----	-----	-----	-----	0.7	0.2	0.8	0.2	-----
Evergreen Forest - C	-----	-----	0.2	0.4	0.4	-----	-----	-----	-----
Evergreen Forest - D	-----	-----	-----	-----	-----	-----	-----	-----	-----
Mixed Forest - B	-----	-----	-----	-----	0.1	0.2	0.2	0.2	-----
Mixed Forest - C	-----	-----	-----	0.2	-----	-----	-----	-----	-----
Mixed Forest - D	-----	-----	-----	-----	-----	-----	-----	-----	-----
Pasture/Hay - B	-----	-----	-----	18.5	464	1441	178	1233	86
Pasture/Hay - C	73	65	1131	1631	2152	1317	41	1848	0.3
Pasture/Hay - D	-----	-----	-----	-----	-----	-----	-----	-----	-----
Row Crops - B, no tile drainage	-----	-----	-----	59	688	3531	754	3633	481
Row Crops - B, tile drained	-----	-----	-----	-----	-----	-----	-----	-----	-----
Row Crops - C, no tile drainage	213	263	2584	3172	5434	2271	72	1689	35
Row Crops - C, tile drained	859	973	13486	5198	8167	9797	604	15124	328
Urban/Recreational/Grasses - B	-----	-----	-----	20	162	24	176	50	-----
Urban/Recreational/Grasses - C	-----	18.3	-----	66	489	5.3	17.0	24	-----
Urban/Recreational/Grasses - D	-----	-----	-----	-----	-----	-----	-----	-----	-----
Woody Wetlands - B,C,D	15.4	15.0	174	254	471	225	13.8	241	47
Emergent Herbaceous Wetlands - B,C,D	2.4	7.8	17.2	5.3	24	3.1	0.4	2.2	-----
Totals	1208	1546	17747	11297	20126	19620	2291	24651	1019

Table 5-8. Pipe Creek Subwatershed Land Use/Hydrologic Group/Tile Drainage Area Percentages

NLCD Land Use Category (MRLC Classifications)	CR-600W percent	CR-900N percent	CR-1400N percent	CR-1100N percent	CR-200W percent	CR-500W percent	SR-128 percent	SR-13 percent	Ungaged percent
Open Water - B,C,D	0.01%	0.01%	0.3%	0.1%	0.2%	0.4%	-----	0.1%	0.1%
Low Intensity Residential - B	-----	-----	-----	1.6%	2.8%	0.4%	10.3%	0.4%	0.8%
Low Intensity Residential - C	-----	9.3%	0.03%	1.6%	2.7%	0.4%	3.4%	0.3%	-----
Low Intensity Residential - D	-----	-----	-----	-----	-----	-----	-----	-----	-----
High Intensity Residential - B	-----	-----	-----	0.1%	0.3%	0.1%	0.6%	0.003%	-----
High Intensity Residential - C	-----	0.2%	0.001%	0.1%	0.1%	0.03%	0.01%	0.01%	-----
High Intensity Residential - D	-----	-----	-----	-----	-----	-----	-----	-----	-----
Commercial/Industrial/Transportation - B	-----	-----	-----	0.1%	1.1%	0.1%	2.2%	-----	-----
Commercial/Industrial/Transportation - C	-----	1.5%	0.2%	0.2%	0.2%	0.04%	-----	0.1%	-----
Commercial/Industrial/Transportation - D	-----	-----	-----	-----	-----	-----	-----	-----	-----
Deciduous Forest - B	-----	-----	-----	0.1%	0.9%	2.8%	2.4%	1.8%	2.8%
Deciduous Forest - C	3.8%	2.2%	1.5%	4.0%	2.1%	1.0%	0.0%	0.6%	0.3%
Deciduous Forest - D	-----	-----	-----	-----	-----	-----	-----	-----	-----
Evergreen Forest - B	-----	-----	-----	-----	0.003%	0.001%	0.04%	0.001%	-----
Evergreen Forest - C	-----	-----	0.001%	0.003%	0.002%	-----	-----	-----	-----
Evergreen Forest - D	-----	-----	-----	-----	-----	-----	-----	-----	-----
Mixed Forest - B	-----	-----	-----	-----	0.001%	0.001%	0.01%	0.001%	-----
Mixed Forest - C	-----	-----	-----	0.002%	-----	-----	-----	-----	-----
Mixed Forest - D	-----	-----	-----	-----	-----	-----	-----	-----	-----
Pasture/Hay - B	-----	-----	-----	0.2%	2.3%	7.3%	7.8%	5.0%	8.5%
Pasture/Hay - C	6.0%	4.2%	6.4%	14.4%	10.7%	6.7%	1.8%	7.5%	0.03%
Pasture/Hay - D	-----	-----	-----	-----	-----	-----	-----	-----	-----
Row Crops - B, no tile drainage	-----	-----	-----	0.5%	3.4%	18.0%	32.9%	14.7%	47.2%
Row Crops - B, tile drained	-----	-----	-----	-----	-----	-----	-----	-----	-----
Row Crops - C, no tile drainage	17.6%	17.0%	14.6%	28.1%	27.0%	11.6%	3.1%	6.9%	3.4%
Row Crops - C, tile drained	71.1%	63.0%	76.0%	46.0%	40.6%	49.9%	26.3%	61.4%	32.2%
Urban/Recreational/Grasses - B	-----	-----	-----	0.2%	0.8%	0.1%	7.7%	0.2%	-----
Urban/Recreational/Grasses - C	-----	1.2%	-----	0.6%	2.4%	0.0%	0.7%	0.1%	-----
Urban/Recreational/Grasses - D	-----	-----	-----	-----	-----	-----	-----	-----	-----
Woody Wetlands - B,C,D	1.3%	1.0%	1.0%	2.2%	2.3%	1.1%	0.6%	1.0%	4.6%
Emergent Herbaceous Wetlands - B,C,D	0.2%	0.5%	0.1%	0.05%	0.1%	0.02%	0.02%	0.01%	-----
Totals	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

Table 5-9. Pipe Creek Subwatershed Incremental Composite Curve Numbers

NLCD Land Use Category (MRLC Classifications)	CR-600W Comp CN	CR-900N Comp CN	CR-1400N Comp CN	CR-1100N Comp CN	CR-200W Comp CN	CR-500W Comp CN	SR-128 Comp CN	SR-13 Comp CN	Ungaged Comp CN
Open Water - B,C,D	0.01	0.01	0.26	0.09	0.19	0.39	-----	0.08	0.06
Low Intensity Residential - B	-----	-----	-----	1.06	1.88	0.25	6.97	0.29	0.56
Low Intensity Residential - C	-----	7.33	0.03	1.26	2.13	0.33	2.67	0.23	-----
Low Intensity Residential - D	-----	-----	-----	-----	-----	-----	-----	-----	-----
High Intensity Residential - B	-----	-----	-----	0.05	0.26	0.05	0.55	0.002	-----
High Intensity Residential - C	-----	0.15	0.001	0.05	0.09	0.03	0.01	0.01	-----
High Intensity Residential - D	-----	-----	-----	-----	-----	-----	-----	-----	-----
Commercial/Industrial/Transportation - B	-----	-----	-----	0.11	0.99	0.06	1.99	-----	-----
Commercial/Industrial/Transportation - C	-----	1.41	0.15	0.15	0.17	0.03	-----	0.07	-----
Commercial/Industrial/Transportation - D	-----	-----	-----	-----	-----	-----	-----	-----	-----
Deciduous Forest - B	-----	-----	-----	0.03	0.49	1.54	1.33	0.98	1.52
Deciduous Forest - C	2.65	1.55	1.08	2.82	1.46	0.67	0.03	0.44	0.24
Deciduous Forest - D	-----	-----	-----	-----	-----	-----	-----	-----	-----
Evergreen Forest - B	-----	-----	-----	-----	0.002	0.001	0.02	0.0005	-----
Evergreen Forest - C	-----	-----	0.001	0.002	0.002	-----	-----	-----	-----
Evergreen Forest - D	-----	-----	-----	-----	-----	-----	-----	-----	-----
Mixed Forest - B	-----	-----	-----	-----	0.0004	0.001	0.01	0.0005	-----
Mixed Forest - C	-----	-----	-----	0.001	-----	-----	-----	-----	-----
Mixed Forest - D	-----	-----	-----	-----	-----	-----	-----	-----	-----
Pasture/Hay - B	-----	-----	-----	0.10	1.41	4.48	4.73	3.05	5.18
Pasture/Hay - C	4.47	3.10	4.71	10.68	7.91	4.97	1.32	5.55	0.02
Pasture/Hay - D	-----	-----	-----	-----	-----	-----	-----	-----	-----
Row Crops - B, no tile drainage	-----	-----	-----	0.42	2.77	14.58	26.67	11.94	38.26
Row Crops - B, tile drained	-----	-----	-----	-----	-----	-----	-----	-----	-----
Row Crops - C, no tile drainage	15.51	14.95	12.81	24.71	23.76	10.18	2.76	6.03	3.03
Row Crops - C, tile drained	55.44	49.11	59.27	35.89	31.65	38.95	20.55	47.85	25.12
Urban/Recreational/Grasses - B	-----	-----	-----	0.12	0.52	0.08	5.00	0.13	-----
Urban/Recreational/Grasses - C	-----	0.91	-----	0.45	1.87	0.02	0.57	0.07	-----
Urban/Recreational/Grasses - D	-----	-----	-----	-----	-----	-----	-----	-----	-----
Woody Wetlands - B,C,D	1.21	0.92	0.93	2.14	2.22	1.09	0.57	0.93	4.37
Emergent Herbaceous Wetlands - B,C,D	0.19	0.48	0.09	0.04	0.11	0.01	0.02	0.01	-----
Composite Curve Numbers	79.47	79.92	79.34	80.17	79.88	77.72	75.76	77.65	78.37
Composite CN Ratio to USGS Gage	1.0035	1.0092	1.0019	1.0123	1.0087	0.9814	0.9567	0.9805	0.9896

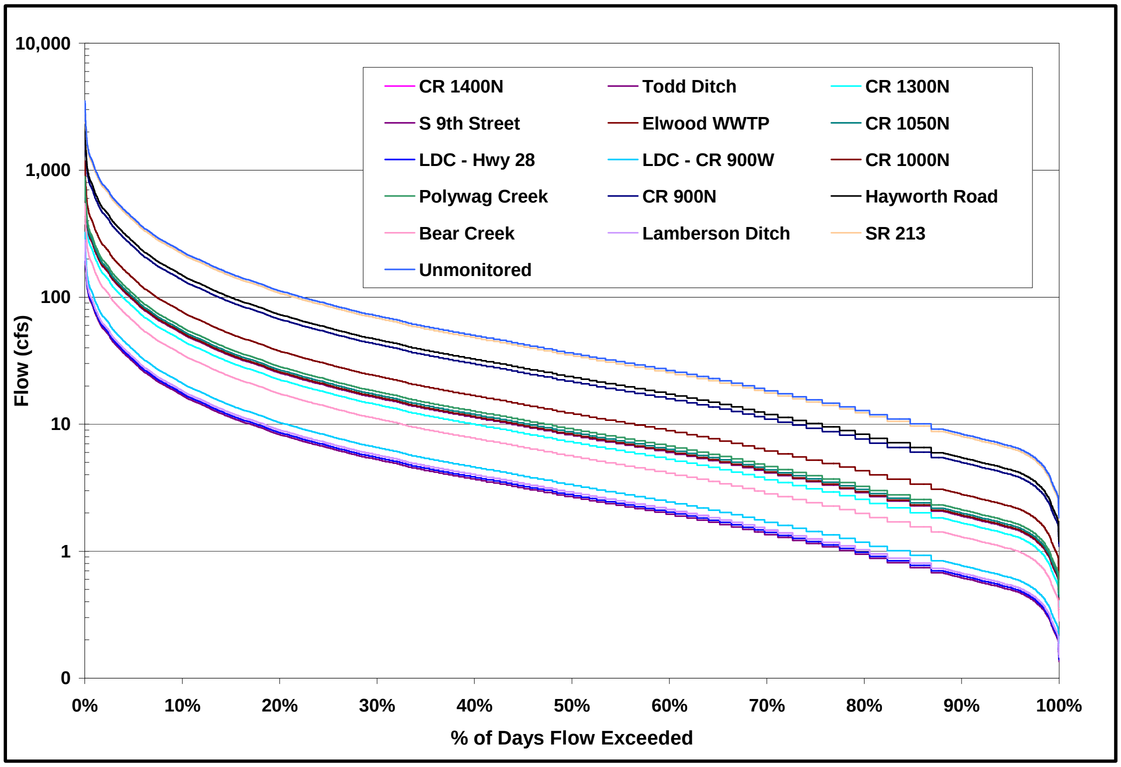

Figure 5-8. Flow Duration Curves for Duck Creek Sampling Stations

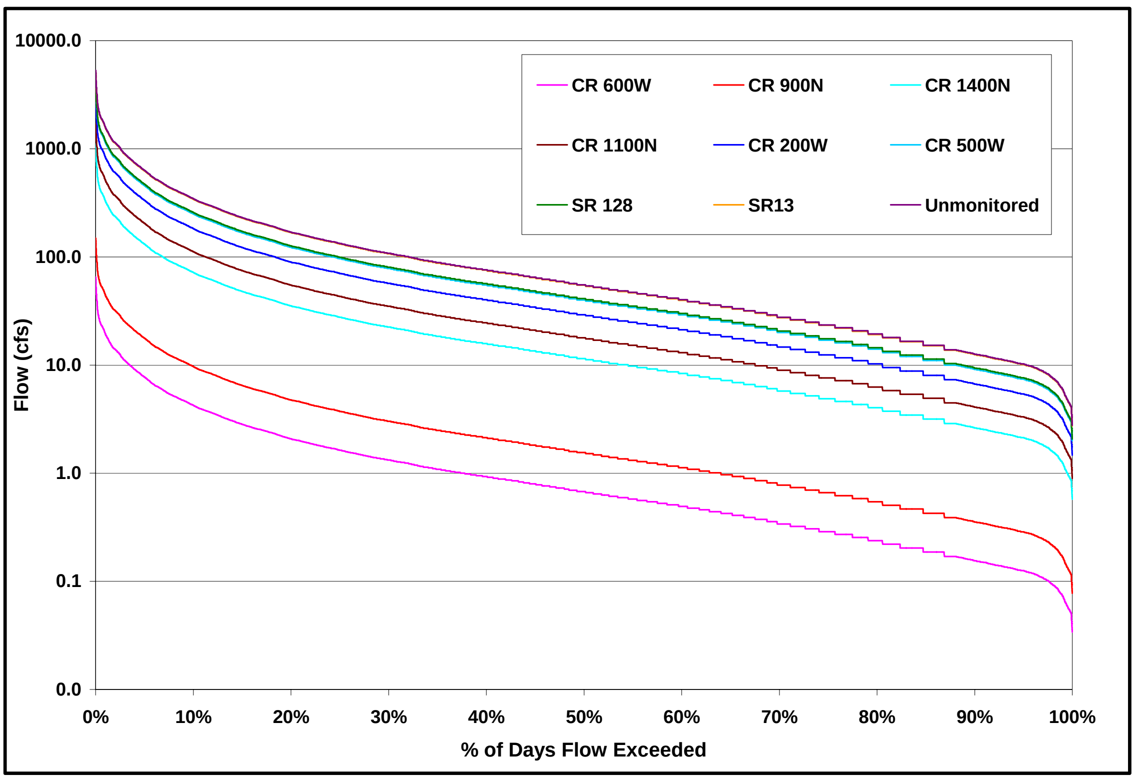

Figure 5-9. Flow Duration Curves for Pipe Creek Sampling Stations

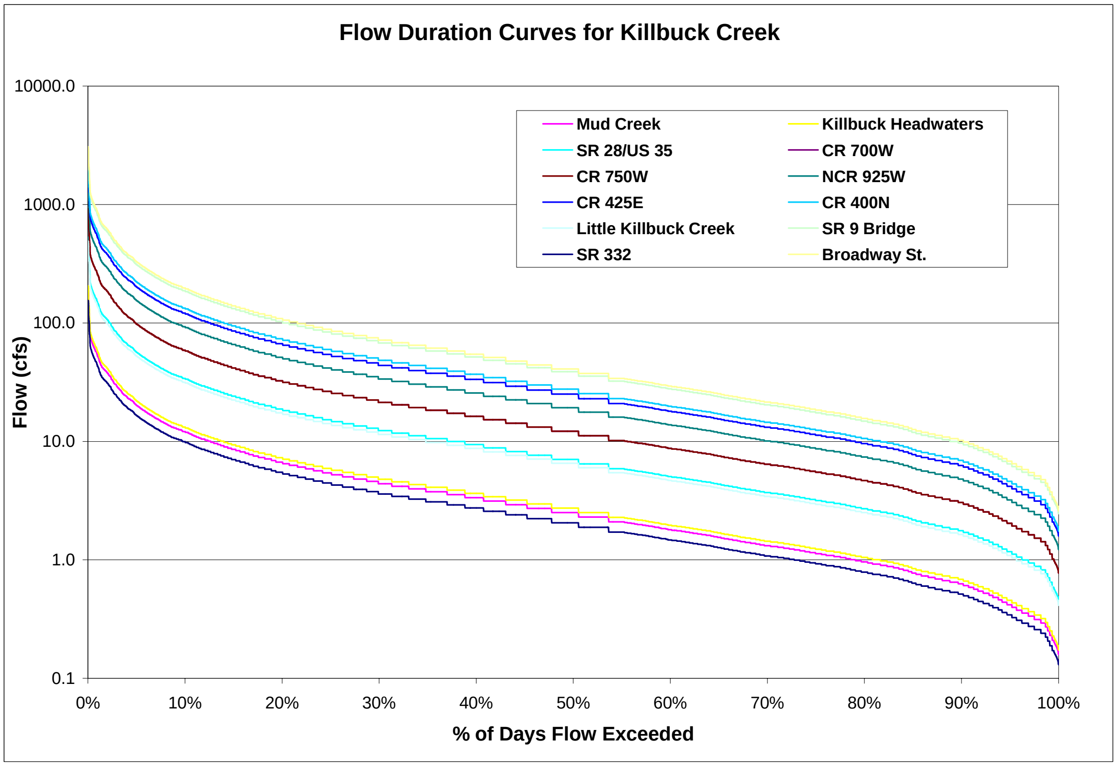

Figure 5-10. Flow Duration Curves for Killbuck Creek Sampling Stations

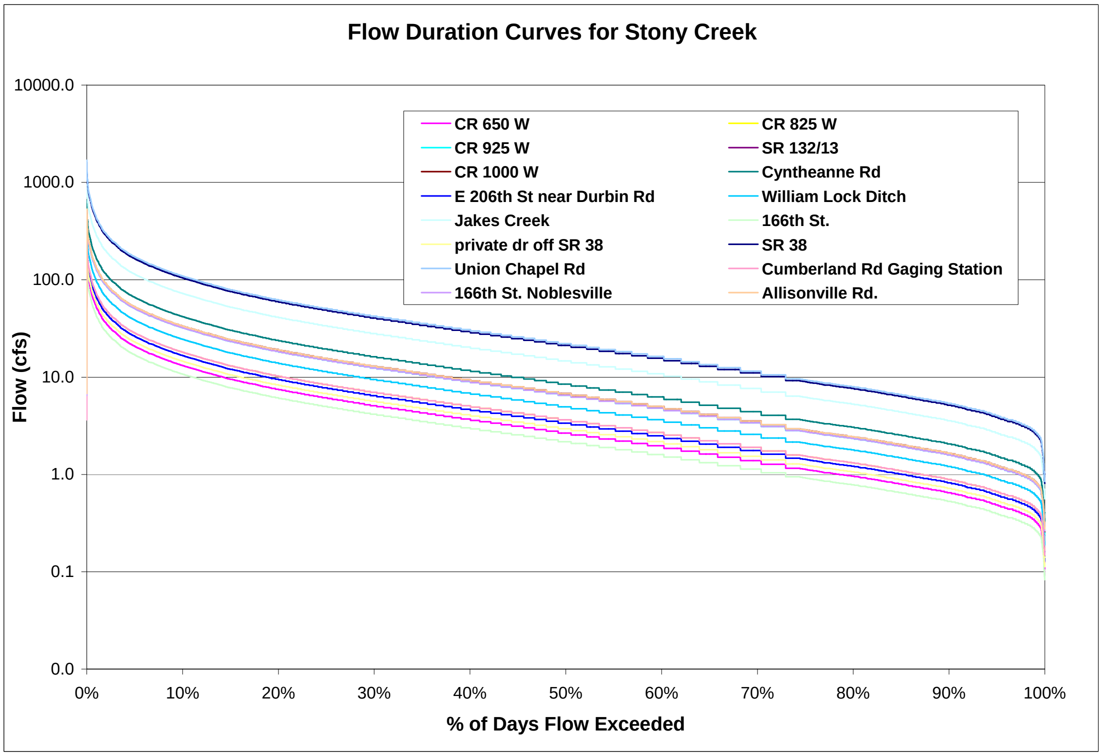

Figure 5-11. Flow Duration Curves for Stony Creek Sampling Stations

Table 5-10. Duck Creek Composite Curve Number Adjustments and Adjusted Median QDC Flows

Duck Creek Monitoring Location	Station ID	Cumulative Drainage Area Ratio to USGS Gage*	Drainage Area Ratio Median Flow (cfs)	Composite CN Ratio	Adjusted Median QDC Flow (cfs)
CR 1400N	WWU060-0010	0.074	2.95	0.9937	2.93
Todd Ditch	WWU060-0011	0.067	2.70	1.0009	2.70
CR 1300N	WWU060-0001	0.183	7.34	0.9908	7.31
S 9th Street	WWU060-0012	0.207	8.28	1.0250	8.27
Elwood WWTP	WWU060-0013	0.211	8.42	0.9913	8.41
CR 1050N	WWU060-0014	0.218	8.74	1.0050	8.73
LDC - Hwy 28	WWU060-0009	0.070	2.80	1.0023	2.80
LDC - CR 900W	WWU060-0015	0.084	3.34	1.0248	3.36
CR 1000N	WWU060-0016	0.307	12.28	0.9629	12.28
Polywag Creek	WWU060-0017	0.226	9.04	1.0250	9.27
CR 900N	WWU060-0018	0.541	21.65	0.9414	21.86
Hayworth Road	WWU060-0019	0.591	23.65	0.9783	23.82
Bear Creek	WWU060-0020	0.142	5.69	0.9953	5.67
Lamberson Ditch	WWU060-0021	0.074	2.96	0.991	2.93
SR 213	WWU060-0003	0.877	35.10	0.9693	35.13
Unmonitored	-----------	0.915	36.59	0.9822	36.59

*compared to USGS gage 03348350 (Pipe Creek near Frankton)

Table 5-11. Pipe Creek Composite Curve Number Adjustments and Adjusted Median QDC Flows

Pipe Creek Monitoring Location	Station ID	Cumulative Drainage Area Ratio to USGS Gage*	Drainage Area Ratio Median Flow (cfs)	Composite CN Ratio	Adjusted Median QDC Flow (cfs)
CR 600W	WWU050-0018	0.017	0.68	1.0035	0.68
CR 900N	WWU050-0017	0.038	1.54	1.0092	1.55
CR 1400N	WWU050-0016	0.287	11.46	1.0019	11.49
CR 1100N	WWU050-0015	0.444	17.78	1.0124	17.89
CR 200W	WWU050-0014	0.726	29.03	1.0087	29.24
CR 500W	WWU050-0005	1.000	40.00	0.9814	40.00
SR 128	WWU050-0013	1.032	41.28	0.9567	41.23
SR13	WWU050-0003	1.377	55.06	0.9805	54.74
Unmonitored	-------	1.391	55.63	0.9896	55.30

*compared to USGS gage 03348350 (Pipe Creek near Frankton)

Table 5-12. Killbuck Creek Composite Curve Number Adjustments and Adjusted Median QDC Flows

Killbuck Creek Monitoring Location	Station ID	Cumulative Drainage Area Ratio to USGS Gage*	Drainage Area Ratio Median Flow (cfs)	Composite CN Ratio	Adjusted Median QDC Flow (cfs)
Mud Creek	WWU040-0028	0.207	2.48	1.0097	2.51
Killbuck Headwaters	WWU040-0027	0.228	2.73	1.0003	2.73
SR28/US 35	WWU040-0026	0.586	7.03	0.9979	7.05
CR 700W	WWU040-0025	1.016	12.20	0.9962	12.20
CR 750W	WWU040-0024	0.382	4.58	0.9888	4.53
NCR 925W	WWU040-0023	1.606	19.27	1.0101	19.24
SR 332	WWU040-0022	0.170	2.04	1.0055	2.06
CR 425E	WWU040-0021	1.960	23.52	0.9977	23.50
CR 400N	WWU040-0020	2.172	26.06	1.0026	26.05
Liitle Killbuck Creek	WWU040-0019	0.542	6.50	1.0050	6.53
SR 9 Bridge	WWU040-0001	3.099	37.19	0.9889	37.16
Broadway St.	WWU040-0018	3.283	39.40	0.97	39.30

*compared to USGS Gage 03348020 near Gaston

Table 5-13. Stony Creek Composite Curve Number Adjustments and Adjusted Median QDC Flows

Stony Creek Monitoring Location	Station ID	Cumulative Drainage Area Ratio to USGS Gage*	Drainage Area Ratio Median Flow (cfs)	Composite CN Ratio	Adjusted Median QDC Flow (cfs)
CR 650 W	WWU070-0034	0.115	2.65	1.0056	2.66
CR 825 W	WWU070-0033	0.158	3.63	0.9976	3.65
CR 925 W	WWU070-0032	0.281	6.46	1.0094	6.50
SR 132/13	WWU070-0031	0.293	6.74	0.9626	6.77
CR 1000 W	WWU070-0030	0.344	7.92	1.0168	7.97
Cyntheanne Rd	WWU070-0029	0.366	8.41	1.0075	8.46
No description	WWU070-0026	0.402	9.24	1.0063	9.30
E 206th St / Durbin Rd	WWU070-0028	0.144	3.31	1.0170	3.37
E 196th St / Mystic Rd	WWU070-0025	0.212	4.88	1.0123	4.95
E 196th St / Mystic Rd	WWU070-0024	0.632	14.54	0.9424	14.65
166th St.	WWU070-0020	0.094	2.17	1.0016	2.17
private dr off SR 38	WWU070-0021	0.128	2.93	1.0141	2.95
SR 38	WWU070-0022	0.913	20.99	1.0124	21.16
Union Chapel Rd	WWU070-0019	0.954	21.94	0.9917	22.10
Cumberland Rd Gage	WWU070-0002	1.000	23.00	0.9965	23.15
166th St. Noblesville	WWU070-0018	0.096	2.21	1.0190	2.25
Allisonville Rd.	WWU070-0016	1.119	25.74	1.0046	25.93

* compared to USGS Gage 03350700 near Noblesville

5.3 DETERMINATION OF REQUIRED REDUCTIONS AND ESTIMATION OF SOURCE CATEGORY LOADS

Once adjusted QDCs and allowable LDCs have been established for each subwatershed, the required load reductions within each subwatershed are determined. In Indiana, state water quality regulations do not allow for any percentile exceedance of the “never-to-exceed” standard for *E. coli* (235 colonies / 100 mL). Since this is the case, the highest observed *E. coli* concentration at any monitoring location defines the magnitude of the required reduction at that location (e.g. if the highest observed *E. coli* concentration at a sampling location was 470 colonies / 100 mL, then the required reduction would be 50%).

By taking the product of the highest observed *E. coli* concentration and the adjusted median QDC value for each monitoring location, the median *E. coli* load at the concentration is determined. The maximum allowable median load at each location is determined as 90% of the *E.coli* “never-to-exceed” standard multiplied by the adjusted median QDC value. This accounts for margin-of-safety. The maximum allowable incremental median load can then be calculated for each subwatershed by subtracting the total loads from all upstream subwatersheds. Tables 5-14 through 5-17 show (a) the highest observed *E. coli* concentrations, (b) the required percent reductions, (c) the median observed *E. coli* loads, (d) the maximum allowable median *E. coli* loads, and (e) the maximum allowable incremental median *E. coli* loads, for each subwatershed in the Duck Creek, Pipe Creek, Killbuck Creek, and Stony Creek watersheds.

Source category loads within each subwatershed are initially calculated via the procedures outlined in Section 4. As discussed, those estimates represent the “total potential conservative loads” of *E. coli* and do not generally account for loading losses due to containment or decay. In order to adjust the estimated loads down to the observed median values, two factors are employed for each subwatershed. The downstream decay factor is calculated based on the distance that pollutant loads must travel from a subwatershed outlet point downstream to the next monitoring location. All downstream decay factors within a watershed are linked together by the relative distances that the pollutant loads must travel. After the downstream decay factors have been established, the overall watershed factors are applied to just the loads originating within each subwatershed in order to match the observed median loads. As an example of this source category load estimation process, Table 5-18 shows the Pipe Creek calculations. Each column in the table represents an individual subwatershed identified by the street location of the sampling station at its outlet (for Pipe Creek, there is no sampling station at the confluence with the West Fork White River, so the most downstream subwatershed is identified as "ungaged"). The table shows that, after application of the downstream decay and overall watershed factors, the estimated loads match the observed median loads.

Table 5-14. Duck Creek Required Reductions and Allowable Median Loads

Duck Creek Monitoring Location	Station ID	Max E. Coli Concentration (col / 100 mL)	Sample Date	Adjusted Median QDC Flow (cfs)	Median E. Coli Load (col / day)	Allowable Median Load (col / day)	Required % Reduction	Allowable Incremental Median Load (col / day)
CR 1400N	WWU060-0010	450	07-May-01	2.93	3.23E+10	1.52E+10	53.0%	1.52E+10
Todd Ditch	WWU060-0011	520	23-Apr-01	2.70	3.44E+10	1.40E+10	59.3%	1.40E+10
CR 1300N	WWU060-0001	340	23-Apr-01	7.31	6.08E+10	3.78E+10	37.8%	8.67E+09
S 9th Street	WWU060-0012	10,000	21-May-01	8.27	2.03E+12	4.28E+10	97.9%	4.99E+09
Elwood WWTP	WWU060-0013	9,200	21-May-01	8.41	1.90E+12	4.36E+10	97.7%	7.43E+08
CR 1050N	WWU060-0014	3,900	21-May-01	8.73	8.34E+11	4.52E+10	94.6%	1.64E+09
LDC - Hwy 28	WWU060-0009	1,700	21-May-01	2.80	1.17E+11	1.45E+10	87.6%	1.45E+10
LDC - CR 900W	WWU060-0015	4,400	21-May-01	3.36	3.62E+11	1.74E+10	95.2%	2.90E+09
CR 1000N	WWU060-0016	2,900	21-May-01	12.28	8.72E+11	6.36E+10	92.7%	9.67E+08
Polywag Creek	WWU060-0017	1,600	23-Apr-01	9.27	3.63E+11	4.80E+10	86.8%	4.80E+10
CR 900N	WWU060-0018	1,700	21-May-01	21.86	9.10E+11	1.13E+11	87.6%	1.62E+09
Hayworth Road	WWU060-0019	1,300	14-May-01	23.82	7.58E+11	1.23E+11	83.7%	1.02E+10
Bear Creek	WWU060-0020	3,300	21-May-01	5.67	4.58E+11	2.93E+10	93.6%	2.93E+10
Lamberson Ditch	WWU060-0021	5,500	14-May-01	2.93	3.95E+11	1.52E+10	96.2%	1.52E+10
SR 213	WWU060-0003	1,300	21-May-01	35.12	1.12E+12	1.82E+11	83.7%	1.40E+10
Unmonitored	-----------	-----------	-----------	36.59	-----------	1.89E+11	-----------	7.60E+09

Table 5-15. Pipe Creek Required Reductions and Allowable Median Loads

Pipe Creek Monitoring Location	Station ID	Max E. Coli Concentration (col / 100 mL)	Sample Date	Adjusted Median QDC Flow (cfs)	Median E. Coli Load (col / day)	Allowable Median Load (col / day)	Required % Reduction	Allowable Incremental Median Load (col / day)
CR 600W	WWU050-0018	2,419	19-Jun-01	0.68	4.01E+10	3.51E+09	91.3%	3.51E+09
CR 900N	WWU050-0017	2,014	26-Jun-01	1.55	7.64E+10	8.03E+09	89.5%	4.52E+09
CR 1400N	WWU050-0016	1,120	03-Jul-01	11.5	3.15E+11	5.95E+10	81.1%	5.15E+10
CR 1100N	WWU050-0015	1,553	12-Jun-01	17.9	6.80E+11	9.26E+10	86.4%	3.31E+10
CR 200W	WWU050-0014	12,033	12-Jun-01	29.2	8.61E+12	1.51E+11	98.2%	5.88E+10
CR 500W	WWU050-0005	14,136	12-Jun-01	40.0	1.38E+13	2.07E+11	98.5%	5.57E+10
SR 128	WWU050-0013	2,142	19-Jun-01	41.2	2.16E+12	2.13E+11	90.1%	6.34E+09
SR13	WWU050-0003	1,553	12-Jun-01	54.7	2.08E+12	2.83E+11	86.4%	7.00E+10
Unmonitored	-------	-------	-------	55.3	-------	2.86E+11	-------	2.92E+09

Table 5-16. Killbuck Creek Required Reductions and Allowable Median Loads

Killbuck Creek Monitoring Location	**Station ID**	**Max E. Coli Concentration (col / 100 mL)**	**Sample Date**	**Adjusted Median QDC Flow (cfs)**	**Median E. Coli Load (col / day)**	**Allowable Median Load (col / day) with 10% MOS**	**Required % Reduction**	**Allowable Incremental Median Load (col / day)**
Mud Creek	WWU040-0028	190	24-Apr-01	2.51	1.17E+10	1.30E+10	0.0%	1.30E+10
Killbuck Headwaters	WWU040-0027	8200	08-May-01	2.73	5.49E+11	1.42E+10	97.4%	1.42E+10
SR 28/US 35	WWU040-0026	2000	24-Apr-01	7.05	3.45E+11	3.65E+10	89.4%	9.35E+09
CR 700W	WWU040-0025	580	08-May-01	12.20	1.73E+11	6.32E+10	63.5%	2.67E+10
CR 750W	WWU040-0024	2400	01-May-01	4.53	2.66E+11	2.35E+10	91.2%	2.35E+10
NCR 925W	WWU040-0023	730	15-May-01	19.24	3.44E+11	9.96E+10	71.0%	1.30E+10
SR 332	WWU040-0022	2400	08-May-01	2.06	1.21E+11	1.06E+10	91.2%	1.06E+10
CR 425E	WWU040-0021	2400	08-May-01	25.06	1.47E+12	1.30E+11	91.2%	1.95E+10
CR 400N	WWU040-0020	2000	08-May-01	27.62	1.35E+12	1.43E+11	89.4%	1.32E+10
Little Killbuck Creek	WWU040-0019	8700	08-May-01	6.53	1.39E+12	3.38E+10	97.6%	3.38E+10
SR 9 Bridge	WWU040-0001	770	08-May-01	38.72	7.30E+11	2.01E+11	72.5%	2.37E+10
Broadway St.	WWU040-0018	610	08-May-01	40.87	6.10E+11	2.12E+11	65.3%	1.11E+10

Table 5-17. Stony Creek Required Reductions and Allowable Median Loads

Stony Creek Monitoring Location	Station ID	Max E. Coli Concentration (col / 100 mL)	Sample Date	Median QDC Flow (cfs)	Median E. Coli Load (col / day)	Allowable Median Load (col / day) w/ 10% MOS	Required % Reduction	Allowable Incremental Median Load (col / day)
CR 650 W	WWU070-0034	580	05-Jun-01	2.66	3.78E+10	1.38E+10	63.5%	1.38E+10
CR 825 W	WWU070-0033	980	19-Jun-01	3.65	8.75E+10	1.89E+10	78.4%	5.09E+09
CR 925 W	WWU070-0032	2400	03-Jul-01	6.50	3.82E+11	3.37E+10	91.2%	1.48E+10
SR 132/13	WWU070-0031	2400	26-Jun-01	6.77	3.98E+11	3.51E+10	91.2%	1.39E+09
CR 1000 W	WWU070-0030	2400	26-Jun-01	7.97	4.68E+11	4.13E+10	91.2%	6.20E+09
Cyntheanne Rd	WWU070-0029	1700	26-Jun-01	8.46	3.52E+11	4.38E+10	87.6%	2.56E+09
Stony Creek at 700026	WWU070-0026	1400	19-Jun-01	9.30	3.19E+11	4.82E+10	84.9%	4.34E+09
E 206th St near Durbin Rd	WWU070-0028	2400	26-Jun-01	3.37	1.98E+11	1.75E+10	91.2%	1.75E+10
William Lock Ditch	WWU070-0025	1300	03-Jul-01	4.95	1.58E+11	2.56E+10	83.7%	8.19E+09
E 196th St	WWU070-0024	2000	12-Jun-01	14.65	7.17E+11	7.59E+10	89.4%	2.05E+09
166th St.	WWU070-0020	2000	19-Jun-01	2.17	1.06E+11	1.12E+10	89.4%	1.12E+10
private dr off SR 38	WWU070-0021	2000	05-Jun-01	2.95	1.44E+11	1.53E+10	89.4%	4.02E+09
SR 38	WWU070-0022	2000	26-Jun-01	21.16	1.04E+12	1.10E+11	89.4%	1.84E+10
Union Chapel Rd	WWU070-0019	2400	05-Jun-01	22.10	1.30E+12	1.14E+11	91.2%	4.86E+09
Cumberland Rd Gaging Station	WWU070-0002	820	19-Jun-01	23.15	4.65E+11	1.20E+11	74.2%	1.20E+11
166th St. Noblesville	WWU070-0018	920	26-Jun-01	2.25	5.08E+10	1.17E+10	77.0%	1.17E+10
Allisonville Rd.	WWU070-0016	770	05-Jun-01	25.93	4.89E+11	1.34E+11	72.5%	2.72E+09

Table 5-18. Pipe Creek *E. coli* Load Estimation and Adjustment Process

Initial Estimated Loads

Source Category	CR 600W	CR 900N	CR 1400N	CR 1100N	CR 200W	CR 500W	SR 128	SR13	Ungaged
Manure Application	2.81E+12	3.19E+12	4.18E+13	2.39E+13	4.00E+13	4.34E+13	3.90E+12	5.56E+13	2.20E+12
Active CAFOs	0	0	9.53E+11	0	0	0	0	1.97E+13	0
Domestic Animals	3.31E+10	1.40E+11	3.99E+11	9.69E+11	2.41E+12	1.13E+12	4.38E+11	8.97E+11	3.01E+10
NPDES	0	1.42E+09	1.66E+08	0	5.68E+09	1.11E+09	1.35E+09	0	0
Non-CAFO Livestock	1.09E+11	9.67E+10	1.40E+12	9.29E+11	1.27E+12	1.33E+12	1.06E+11	1.50E+12	7.81E+10
Failing Septic	1.48E+11	6.53E+11	1.75E+12	1.96E+12	6.26E+12	4.02E+12	3.29E+11	2.98E+12	1.36E+11
CSOs	0	0	0	0	9.63E+11	0	4.35E+11	0	0
Wildlife	2.43E+11	3.11E+11	3.57E+12	2.27E+12	4.04E+12	3.94E+12	4.60E+11	4.95E+12	2.05E+11
Totals	3.34E+12	4.39E+12	4.99E+13	3.01E+13	5.49E+13	5.39E+13	5.67E+12	8.57E+13	2.65E+12

Distance to Station (m)	2539	11014	8283	4182	9268	2312	12105	1993	-------
Relative Length	1.00	4.34	3.26	1.65	3.65	0.91	4.77	0.78	-------

Watershed Factor	83.2	61.95	159.5	45.1	6.42	3.982	71	13.45	55.58
Downstream Decay	0.137	0.032	0.042	0.083	0.038	0.150	0.029	0.175	-------

Adjusted Loads

Source Category	CR 600W	CR 900N	CR 1400N	CR 1100N	CR 200W	CR 500W	SR 128	SR13	Ungaged
Manure Application	3.37E+10	5.15E+10	2.62E+11	5.31E+11	6.23E+12	1.09E+13	5.49E+10	4.14E+12	3.95E+10
Active CAFOs	0	0	5.97E+09	0	0	0	0	1.46E+12	0
Domestic Animals	3.98E+08	2.26E+09	2.50E+09	2.15E+10	3.75E+11	2.84E+11	6.17E+09	6.67E+10	5.42E+08
NPDES	0	2.29E+07	1.04E+06	0	8.84E+08	2.78E+08	1.91E+07	0	0
Non-CAFO Livestock	1.31E+09	1.56E+09	8.79E+09	2.06E+10	1.97E+11	3.35E+11	1.49E+09	1.11E+11	1.40E+09
Failing Septic	1.78E+09	1.05E+10	1.10E+10	4.35E+10	9.75E+11	1.01E+12	4.64E+09	2.22E+11	2.45E+09
CSOs	0	0	0	0	1.50E+11	0	6.12E+09	0	0
Wildlife	2.92E+09	5.02E+09	2.24E+10	5.03E+10	6.30E+11	9.90E+11	6.48E+09	3.68E+11	3.68E+09
Upstream Load	0	5.50E+09	2.41E+09	1.32E+10	5.65E+10	3.23E+11	2.08E+12	6.22E+10	1.12E+12
Subwatershed sum	4.01E+10	7.09E+10	3.13E+11	6.67E+11	8.56E+12	1.35E+13	7.98E+10	6.37E+12	4.76E+10
Cumulative sum	4.01E+10	7.64E+10	3.15E+11	6.80E+11	8.61E+12	1.38E+13	2.16E+12	6.43E+12	1.17E+12

Observed Median Load	4.01E+10	7.64E+10	3.15E+11	6.80E+11	8.61E+12	1.38E+13	2.16E+12	6.43E+12	-------

5.4 DETERMINATION OF SUBWATERSHED SOURCE CATEGORY PERCENT REDUCTIONS

After subwatershed loads have been estimated and adjusted to observations, percent reduction allocations are made in order to meet the subwatershed reductions identified in Tables 5-14 through 5-17. This is achieved through an analysis of the relative percentages of source category loads within each subwatershed and the application of targeted percent reductions to the individual source categories that contribute the greatest loads. Whenever possible, consistency in the level of source category load reductions is preserved across subwatersheds.

As an example of this subwatershed load reduction process, Table 5-19 shows the Pipe Creek calculations. As percent reductions are entered in the percent reduction table, commensurate *E. coli* median load allocations are recalculated in the load allocation table. The relative percent error reflects a comparison of the calculated load allocation with the targeted median subwatershed loads. By keeping all of the percent reductions at round number values, the resultant percent errors achieved are all less than zero, indicating that the cumulative reduced load is less than the targeted median values throughout the watershed. The additional load reduction can be used as part of the margin of safety for this TMDL.

As can be seen from the Table 5-19, large percent reductions in *E. coli* loadings are required from some source categories in order to meet targeted median loads. Percent reductions for *E. coli* loads associated with the agricultural application of manure, non-CAFO and non-CFO related free-ranging livestock, and failing septic systems are all generally higher than 80% and are as high as 99% for some subwatersheds. Other source categories, such as domestic animals, wildlife, and CSOs, also need large percent reductions in *E. coli* loads in selected subwatersheds.

Table 5-19. Pipe Creek *E. coli* Load Allocations and Source Category Percent Reductions

Subwatershed	CR 600W	CR 900N	CR 1400N	CR 1100N	CR 200W	CR 500W	SR 128	SR13	Ungaged
Required % Reduction	91.26%	89.50%	81.12%	86.38%	98.24%	98.50%	90.13%	86.38%	-------
Target Median Load	3.51E+09	8.02E+09	5.95E+10	9.26E+10	1.51E+11	2.07E+11	2.14E+11	8.76E+11	-------

Median Load Allocations

Source Category	CR 600W	CR 900N	CR 1400N	CR 1100N	CR 200W	CR 500W	SR 128	SR13	Ungaged
Manure Application	1.69E+09	2.58E+09	3.67E+10	3.72E+10	6.23E+10	1.09E+11	2.75E+10	4.14E+11	3.95E+09
Active CAFOs	------	------	5.97E+09	------	------	------	------	2.20E+11	------
Domestic Animals	1.99E+08	1.13E+09	1.25E+09	1.07E+10	1.87E+10	1.42E+10	3.08E+09	3.33E+10	2.71E+08
NPDES	------	2.29E+07	1.04E+06	------	8.84E+08	2.78E+08	1.91E+07	------	------
Non-CAFO Livestock	6.53E+07	7.80E+07	1.23E+09	1.44E+09	1.97E+09	3.35E+09	7.44E+08	1.11E+10	1.40E+08
Failing Septic	3.55E+08	1.58E+09	1.65E+09	6.52E+09	1.95E+10	2.02E+10	2.32E+09	2.22E+10	2.45E+08
CSOs	------	------	------	------	4.50E+09	------	6.12E+09	------	------
Wildlife	1.17E+09	2.01E+09	8.94E+09	2.01E+10	3.15E+10	4.95E+10	2.59E+09	1.47E+11	1.47E+09
Upstream Load	0	4.76E+08	2.49E+08	2.35E+09	6.52E+09	5.48E+09	3.04E+10	2.09E+09	1.48E+11
Subwatershed Sum	3.47E+09	7.39E+09	5.57E+10	7.60E+10	1.39E+11	1.97E+11	4.23E+10	8.47E+11	6.08E+09
Cumulative Sum	3.47E+09	7.87E+09	5.60E+10	7.83E+10	1.46E+11	2.02E+11	7.27E+10	8.50E+11	1.54E+11

Relative % Error	-1.04%	-1.93%	-5.92%	-15.38%	-3.63%	-2.48%	-65.94%	-3.02%	-------

Subwatershed Percent Reductions

Source Category	CR 600W	CR 900N	CR 1400N	CR 1100N	CR 200W	CR 500W	SR 128	SR13	Ungaged
Manure Application	**95%**	**95%**	**86%**	**93%**	**99%**	**99%**	**50%**	**90%**	**90%**
Active CAFOs	------	------	0%	------	------	------	------	**85%**	------
Domestic Animals	**50%**	**50%**	**50%**	**50%**	**95%**	**95%**	**50%**	**50%**	**50%**
NPDES	------	0%	0%	------	0%	0%	0%	------	------
Non-CAFO Livestock	**95%**	**95%**	**86%**	**93%**	**99%**	**99%**	**50%**	**90%**	**90%**
Failing Septic	**80%**	**85%**	**85%**	**85%**	**98%**	**98%**	**50%**	**90%**	**90%**
CSOs	------	------	------	------	**97%**	------	0%	------	------
Wildlife	**60%**	**60%**	**60%**	**60%**	**95%**	**95%**	**60%**	**60%**	**60%**

6.0 ALLOCATIONS

A TMDL is the total mass of a pollutant that a water body can assimilate and still achieve water quality standards. TMDLs are commonly expressed in units of mass per time. Other "concentration-based" TMDLs are frequently expressed in terms of loading percent reductions required. This approach allows for a continuum of allowable loads that vary with flow. The TMDLs for Duck Creek, Pipe Creek, Killbuck Creek, and Stony Creek are expressed in terms of percent reductions required.

Components of a TMDL include the sum of individual wasteload allocations (WLAs) for point sources, the sum of load allocations (LAs) for nonpoint sources and natural background levels, and an implicit or explicit margin of safety (MOS) that accounts for the uncertainty in the linkage between pollutant sources and the receiving water quality. Conceptually, this is defined by the equation:

$$\text{TMDL} = \Sigma \text{ WLAs} + \Sigma \text{ LAs} + \text{MOS}$$

For Duck Creek, Pipe Creek, Killbuck Creek, and Stony Creek, *E. coli* TMDLs were established via the steps described in Sections 4 and 5, listed as follows:

- Identification of contributing source categories
- Estimation of source contributions to existing conditions
- Determination of Required Reductions
- Allocation of Reductions to Source Categories with each Subwatershed

6.1 DUCK CREEK TMDL

The Duck Creek *E. coli* TMDL was conducted for the 16 subwatersheds depicted in Figure 5-4. In addition to the high percentages of row crop and pasture lands within the watershed, the city of Elwood also has 14 CSOs and a recent history of discharge violations (both WWTP and CSO discharges). An existing Agreed Order (IDEM, 2002) between the City of Elwood and IDEM stipulates additional monitoring and planning requirements for the Elwood discharges. It is expected that these requirements will result in significant *E. coli* load reductions from these sources. Accordingly, the TMDL includes some targeted reductions for these sources.

6.1.1 EXISTING CONDITIONS

Table 6-1 shows the estimated existing distribution of *E. coli* loads for each of the Duck Creek subwatersheds. The same distribution is shown in Table 6-2, but is presented in terms of the percentages from each source category. Headwater subwatersheds are denoted in yellow. The existing conditions distributions show that, in the headwater subwatersheds and the larger incremental subwatersheds (CR 1300N, Hayworth Road, SR213), application of manure to row crops and pasture lands represents the largest percentage of *E. coli* loads. In the smaller urban subwatersheds, loads passed from upstream become a greater factor, as do loads from failing septic systems, CSOs, and domestic animals.

Table 6-1. Existing Condition *E. coli* Loads within Duck Creek Subwatersheds

Source Category	CR 1400N	Todd Ditch	CR 1300N	S 9th Street	Elwood WWTP	CR 1050N	LDC - Hwy 28	LDC - CR900W
Manure Application	2.40E+10	2.75E+10	3.75E+10	6.13E+11	7.59E+10	1.20E+11	9.58E+10	3.90E+10
Active CAFOs	4.38E+09	2.63E+09	------	------	------	------	------	------
Domestic Animals	1.08E+08	1.24E+08	2.33E+08	5.64E+11	1.02E+11	7.46E+10	1.22E+09	1.08E+11
NPDES	------	------	------	------	5.25E+09	------	------	------
Non-CAFO Livestock	1.29E+09	1.24E+09	2.74E+09	2.94E+10	2.69E+10	1.40E+10	6.66E+09	4.79E+09
Failing Septic	4.75E+08	5.37E+08	9.23E+08	2.63E+11	4.31E+10	2.99E+10	4.52E+09	5.38E+10
CSOs	------	------	------	4.19E+11	1.09E+11	------	------	1.15E+11
Wildlife	2.06E+09	2.35E+09	3.24E+09	1.27E+11	1.79E+10	1.98E+10	8.47E+09	2.85E+10
Upstream Load	0	0	1.61E+10	9.30E+09	1.51E+12	5.75E+11	0	1.39E+10
Subwatershed Sum	3.23E+10	3.44E+10	4.47E+10	2.02E+12	3.80E+11	2.59E+11	1.17E+11	3.49E+11
Cumulative Sum	3.23E+10	3.44E+10	6.08E+10	2.02E+12	1.89E+12	8.34E+11	1.17E+11	3.63E+11

Source Category	CR 1000N	Polywag Creek	CR 900N	Hayworth Road	Bear Creek	Lamberson Ditch	SR 213	Ungaged
Manure Application	1.57E+11	3.03E+11	2.63E+11	4.93E+11	3.71E+11	3.17E+11	7.12E+11	5.74E+10
Active CAFOs	------	9.13E+09	------	6.73E+10	------	------	------	6.03E+09
Domestic Animals	4.39E+10	2.96E+09	4.63E+09	3.76E+09	2.33E+09	5.88E+09	7.71E+09	4.05E+08
NPDES	------	------	------	------	------	------	------	------
Non-CAFO Livestock	1.17E+10	2.12E+10	7.78E+10	6.12E+10	4.53E+10	2.47E+10	1.20E+11	5.46E+09
Failing Septic	2.55E+10	6.99E+09	1.98E+10	1.56E+10	1.02E+10	1.92E+10	3.41E+10	1.77E+09
CSOs	------	------	------	------	------	------	------	------
Wildlife	3.13E+10	1.98E+10	2.60E+10	3.84E+10	2.94E+10	2.81E+10	6.51E+10	5.15E+09
Upstream Load	6.03E+11	0	5.18E+11	7.96E+10	0	0	1.80E+11	3.55E+11
Subwatershed Sum	2.69E+11	3.63E+11	3.92E+11	6.79E+11	4.58E+11	3.95E+11	9.38E+11	7.62E+10
Cumulative Sum	8.72E+11	3.63E+11	9.10E+11	7.58E+11	4.58E+11	3.95E+11	1.12E+12	4.31E+11

Table 6-2. Source Category Percentages of Existing Condition Loads within Duck Creek Subwatersheds

Source Category	CR 1400N	Todd Ditch	CR 1300N	S 9th Street	Elwood WWTP	CR 1050N	LDC - Hwy 28	LDC - CR900W
Manure Application	74.2%	80.0%	61.7%	30.3%	4.0%	14.4%	82.1%	10.8%
Active CAFOs	13.6%	7.6%	-----	-----	-----	-----	-----	-----
Domestic Animals	0.3%	0.4%	0.4%	27.9%	5.4%	8.9%	1.0%	29.7%
NPDES	-----	-----	-----	-----	0.3%	-----	-----	-----
Non-CAFO Livestock	4.0%	3.6%	4.5%	1.5%	1.4%	1.7%	5.7%	1.3%
Failing Septic	1.5%	1.6%	1.5%	13.0%	2.3%	3.6%	3.9%	14.9%
CSOs	-----	-----	-----	20.7%	5.8%	-----	-----	31.7%
Wildlife	6.4%	6.8%	5.3%	6.3%	0.9%	2.4%	7.3%	7.9%
Upstream Load	-----	-----	26.5%	0.5%	79.9%	69.0%	-----	3.8%
	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

Source Category	CR 1000N	Polywag Creek	CR 900N	Hayworth Road	Bear Creek	Lamberson Ditch	SR 213	Ungaged
Manure Application	18.0%	83.5%	28.9%	65.0%	81.0%	80.3%	63.7%	13.3%
Active CAFOs	-----	2.5%	-----	8.9%	-----	-----	-----	1.4%
Domestic Animals	5.0%	0.8%	0.5%	0.5%	0.5%	1.5%	0.7%	0.1%
NPDES	-----	-----	-----	-----	-----	-----	-----	-----
Non-CAFO Livestock	1.3%	5.8%	8.6%	8.1%	9.9%	6.3%	10.7%	1.3%
Failing Septic	2.9%	1.9%	2.2%	2.1%	2.2%	4.9%	3.1%	0.4%
CSOs	-----	-----	-----	-----	-----	-----	-----	-----
Wildlife	3.6%	5.4%	2.9%	5.1%	6.4%	7.1%	5.8%	1.2%
Upstream Load	69.1%	-----	57.0%	10.5%	-----	-----	16.1%	82.3%
	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

6.1.2 INCREMENTAL WATERSHED SOURCE ALLOCATIONS

In order to meet targeted median *E. coli* loads associated with the “never-to-exceed” water quality standard, the percent reductions specified in Table 6-3 were applied to the existing loads in Table 6-1. In determining the percent reduction magnitudes, those source categories contributing the greatest percentages of the existing loads were addressed first. Similar source categories (e.g. non-CFO associated livestock and manure application) were commonly assigned the same percent reductions. Significant effort was placed in preserving consistency across subwatersheds in assigning individual source category reductions.

The allocation shows that, in the portion of the Duck Creek watershed upstream of Elwood, 60% reductions in *E. coli* loads associated with manure application, CFOs, other livestock, and wildlife will achieve the water quality standard. A septic load reduction of 30% is also required in the Todd Ditch subwatershed. In the urban Elwood subwatersheds, high percentages (i.e. ≥ 95%) of load reductions are required from all contributing source categories in order to achieve the standard. For the remaining headwater subwatersheds, high reduction percentages (i.e. ≥ 90%) in agriculture-related activities are required, while load reductions from wildlife, failing septic systems, and domestic animals range from 50-90%.   This trend is also seen for the downstream portion of the Duck Creek main stem subwatersheds.

Table 6-4 shows the projected distribution of *E. coli* loads for each Duck Creek subwatershed after reduction allocations were established. The same distribution is shown in Table 6-5, but is presented in terms of the percentages from each source category.

Table 6-3.	Percent TMDL Load Reductions Applied to Source Categories within Each Duck Creek Subwatershed

Source Category	CR 1400N	Todd Ditch	CR 1300N	S 9th Street	Elwood WWTP	CR 1050N	LDC - Hwy 28	LDC - CR900W
Manure Application	**60%**	**60%**	**60%**	**99%**	**99%**	**90%**	**90%**	**96%**
Active CAFOs	**60%**	**60%**	------	------	------	------	------	------
Domestic Animals	0%	0%	0%	**98%**	**98%**	**90%**	90%	**95%**
NPDES	------	------	------	------	0%	------	------	------
Non-CAFO Livestock	**60%**	**60%**	**60%**	**99%**	**99%**	**90%**	**90%**	**96%**
Failing Septic	0%	**30%**	0%	**98%**	**98%**	**90%**	**90%**	**96%**
CSOs	------	------	------	**98%**	**98%**	------	------	**96%**
Wildlife	**60%**	**60%**	**60%**	**95%**	**95%**	**60%**	**60%**	**95%**

Source Category	CR 1000N	Polywag Creek	CR 900N	Hayworth Road	Bear Creek	Lamberson Ditch	SR 213	Ungaged
Manure Application	**95%**	**90%**	**90%**	**86%**	**97%**	**98%**	**85%**	**85%**
Active CAFOs	------	**60%**	------	**85%**	------	------	------	**50%**
Domestic Animals	**75%**	0%	0%	0%	0%	**75%**	**50%**	**50%**
NPDES	------	------	------	------	------	------	------	------
Non-CAFO Livestock	**95%**	**90%**	**90%**	**86%**	**97%**	**98%**	**85%**	**85%**
Failing Septic	**95%**	**90%**	**85%**	**75%**	**75%**	**95%**	**80%**	**60%**
CSOs	------	------	------	------	------	------	------	------
Wildlife	**60%**	**60%**	**60%**	**60%**	**60%**	**80%**	**60%**	**60%**

Table 6-4. Projected Duck Creek Subwatershed *E. coli* Loads after Load Allocation

Source Category	CR 1400N	Todd Ditch	CR 1300N	S 9th Street	Elwood WWTP	CR 1050N	LDC - Hwy 28	LDC - CR900W
Manure Application	**9.59E+09**	**1.10E+10**	**1.50E+10**	**6.13E+09**	**7.59E+08**	**1.20E+10**	**9.58E+09**	**1.56E+09**
Active CAFOs	**1.75E+09**	**1.05E+09**	-----	-----	-----	-----	-----	-----
Domestic Animals	1.08E+08	1.24E+08	2.33E+08	**1.13E+10**	**2.04E+09**	**7.46E+09**	1.22E+08	**5.38E+09**
NPDES	-----	-----	-----	-----	5.25E+09	-----	-----	-----
Non-CAFO Livestock	**5.17E+08**	**4.98E+08**	**1.09E+09**	**2.94E+08**	**2.69E+08**	**1.40E+09**	**6.66E+08**	**1.92E+08**
Failing Septic	4.75E+08	3.76E+08	9.23E+08	**5.26E+09**	**8.62E+08**	**2.99E+09**	**4.52E+08**	**2.15E+09**
CSOs	-----	-----	-----	**8.37E+09**	**2.19E+09**	-----	-----	**4.59E+09**
Wildlife	**8.26E+08**	**9.41E+08**	**1.29E+09**	**6.37E+09**	**8.97E+08**	**7.94E+09**	**3.39E+09**	**1.42E+09**
Upstream Load	------	------	6.60E+09	3.85E+09	3.11E+10	1.32E+10	------	1.70E+09
Subwatershed Sum	1.33E+10	1.40E+10	1.86E+10	3.77E+10	1.23E+10	3.18E+10	1.42E+10	1.53E+10
Cumulative Sum	1.33E+10	1.40E+10	2.52E+10	4.16E+10	4.33E+10	4.50E+10	1.42E+10	1.70E+10
Percent Under Target	-12.6%	0.0%	-33.5%	-3.0%	-0.5%	-0.5%	-2.1%	-2.4%

Source Category	CR 1000N	Polywag Creek	CR 900N	Hayworth Road	Bear Creek	Lamberson Ditch	SR 213	Ungaged
Manure Application	**7.85E+09**	**3.03E+10**	**2.63E+10**	**6.90E+10**	**1.11E+10**	**6.35E+09**	**1.07E+11**	**8.61E+09**
Active CAFOs	-----	**3.65E+09**	-----	**1.01E+10**	-----	-----	-----	**3.01E+09**
Domestic Animals	**1.10E+10**	2.96E+09	4.63E+09	3.76E+09	**2.33E+09**	**1.47E+09**	**3.86E+09**	**2.03E+08**
NPDES	-----	-----	-----	-----	-----	-----	-----	-----
Non-CAFO Livestock	**5.83E+08**	**2.12E+09**	**7.78E+09**	**8.57E+09**	**1.36E+09**	**4.95E+08**	**1.80E+10**	**8.18E+08**
Failing Septic	**1.27E+09**	**6.99E+08**	**2.98E+09**	**3.89E+09**	**2.55E+09**	**9.58E+08**	**6.82E+09**	**7.08E+08**
CSOs	-----	-----	-----	-----	-----	-----	-----	-----
Wildlife	**1.25E+10**	**7.90E+09**	**1.04E+10**	**1.54E+10**	**1.17E+10**	**5.61E+09**	**2.60E+10**	**2.06E+09**
Upstream Load	3.03E+10	------	5.68E+10	9.53E+09	------	------	1.46E+10	5.59E+10
Subwatershed Sum	3.32E+10	4.76E+10	5.21E+10	1.11E+11	2.91E+10	1.49E+10	1.61E+11	1.54E+10
Cumulative Sum	6.35E+10	4.76E+10	1.09E+11	1.20E+11	2.91E+10	1.49E+10	1.76E+11	7.13E+10
Percent Under Target	-0.2%	-0.7%	-3.8%	-2.6%	-0.8%	-2.1%	-3.2%	-------

Table 6-5. Projected Source Category Percentages of Duck Creek Subwatershed *E. coli* Loads after Load Allocation

Source Category	CR 1400N	Todd Ditch	CR 1300N	S 9th Street	Elwood WWTP	CR 1050N	LDC - Hwy 28	LDC - CR900W
Manure Application	72.3%	78.6%	59.7%	14.8%	1.7%	26.8%	67.4%	9.2%
Active CAFOs	13.2%	7.5%	-----	-----	-----	-----	-----	-----
Domestic Animals	0.8%	0.9%	0.9%	27.1%	4.7%	16.6%	0.9%	31.6%
NPDES	-----	-----	-----	-----	12.1%	-----	-----	-----
Non-CAFO Livestock	3.9%	3.6%	4.4%	0.7%	0.6%	3.1%	4.7%	1.1%
Failing Septic	3.6%	2.7%	3.7%	12.7%	2.0%	6.7%	3.2%	12.7%
CSOs	-----	-----	-----	20.1%	5.1%	-----	-----	27.0%
Wildlife	6.2%	6.7%	5.1%	15.3%	2.1%	17.6%	23.8%	8.4%
Upstream Load	-----	-----	26.2%	9.3%	71.7%	29.2%	-----	10.0%
Total	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

Source Category	CR 1000N	Polywag Creek	CR 900N	Hayworth Road	Bear Creek	Lamberson Ditch	SR 213	Ungaged
Manure Application	12.4%	63.6%	24.2%	57.4%	38.2%	42.6%	60.6%	12.1%
Active CAFOs	-----	7.7%	-----	8.4%	-----	-----	-----	4.2%
Domestic Animals	17.3%	6.2%	4.2%	3.1%	8.0%	9.9%	2.2%	0.3%
NPDES	-----	-----	-----	-----	-----	-----	-----	-----
Non-CAFO Livestock	0.9%	4.5%	7.1%	7.1%	4.7%	3.3%	10.2%	1.1%
Failing Septic	2.0%	1.5%	2.7%	3.2%	8.8%	6.4%	3.9%	1.0%
CSOs	-----	-----	-----	-----	-----	-----	-----	-----
Wildlife	19.7%	16.6%	9.6%	12.8%	40.4%	37.7%	14.8%	2.9%
Upstream Load	47.7%	-----	52.2%	7.9%	-----	-----	8.3%	78.4%
Total	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

6.1.3 WASTE LOAD ALLOCATIONS (WLAS)

E. coli loads from CFOs, NPDES facilities, and CSOs comprise the WLA component of the TMDL. Summarizing the subwatershed loads from those source categories in Table 6-4 results in the WLA component for each subwatershed. Comparison of those loads with the sum of the same categories from Table 6-1 results in the WLA percent reduction required for each subwatershed. Table 6-6 shows the TMDL allocation components, including the WLA, for each of the Duck Creek subwatersheds. Table 6-6 also shows the WLA percent reductions required for each subwatershed. For the entire Duck Creek watershed, a WLA percent reduction of 94.6% is required in order to meet the “never-to-exceed” *E. coli* standard.

Table 6-6. Duck Creek Median Load and Percent Reduction: TMDL Components

Subwatershed	TMDL Median Load Allocations			Percent Reductions	
	WLA	LA	MOS	WLA	LA
CR 1400N	1.75E+09	1.12E+10	1.52E+09	60.0%	59.8%
Todd Ditch	1.05E+09	1.28E+10	1.40E+09	60.0%	59.8%
CR 1300N	0	1.86E+10	3.78E+09	0.0%	58.4%
S 9th Street	8.37E+09	2.93E+10	4.28E+09	98.0%	98.2%
Elwood WWTP	7.44E+09	4.82E+09	4.36E+09	93.5%	98.2%
CR 1050N	0	3.18E+10	4.52E+09	0.0%	87.7%
LDC - Hwy 28	0	1.42E+10	1.45E+09	0.0%	87.8%
LDC - CR900W	4.59E+09	1.07E+10	1.74E+09	96.0%	95.4%
CR 1000N	0	3.32E+10	6.36E+09	0.0%	87.7%
Polywag Creek	3.65E+09	4.40E+10	4.80E+09	60.0%	87.6%
CR 900N	0	5.21E+10	1.13E+10	0.0%	86.7%
Hayworth Road	1.01E+10	1.01E+11	1.23E+10	85.0%	83.6%
Bear Creek	0	2.91E+10	2.93E+09	0.0%	93.6%
Lamberson Ditch	0	1.49E+10	1.52E+09	0.0%	96.2%
SR 213	0	1.61E+11	1.82E+10	0.0%	82.8%
Ungaged	3.01E+09	1.24E+10	0	50.0%	82.3%
Duck Creek Watershed	**4.00E+10**	**5.81E+11**	**8.05E+10**	**94.6%**	**90.4%**

6.1.4 LOAD ALLOCATIONS

E. coli loads from application of agricultural manure, domestic pets, non-CFO related free-ranging livestock, failing septic systems, and wildlife comprise the LA component of the TMDL. Summarizing the subwatershed loads from those source categories in Table 6-4 results in the LA component for each subwatershed. Comparison of those loads with the sum of the same categories from Table 6-1 results in the LA percent reduction required for each subwatershed. Table 6-6 shows the TMDL allocation components, including the LA, for each of the Duck Creek subwatersheds. Table 6-6 also shows the LA percent reductions required for each subwatershed. For the entire Duck Creek watershed, a LA percent reduction of 90.4% is required in order to meet the “never-to-exceed” *E. coli* standard.

6.2 PIPE CREEK TMDL

The Pipe Creek *E. coli* TMDL was conducted for the 9 subwatersheds depicted in Figure 5-5. In addition to high percentages of row crop and pasture lands, the watershed also includes the communities of Alexandria, Frankton, Summitville, Gaston, and Orestes. There are 7 NPDES discharges in the watershed that may potentially provide *E. coli* loadings to Pipe Creek. One of those permits is for the City of Summitville’s two CSO outfalls. The cities of Frankton and Alexandria also have active CSO outfalls, one in each community. The TMDL does include some targeted reductions for the CSOs.

6.2.1 EXISTING CONDITIONS

Table 6-7 shows the estimated existing distribution of *E. coli* loads for each of the Pipe Creek subwatersheds. The same distribution is shown in Table 6-8, but is presented in terms of the percentages from each source category. A single headwater subwatershed is denoted in yellow. The existing conditions distributions show that application of manure to row crops and pasture lands represents the largest percentage of *E. coli* loads in most of the subwatersheds. Failing septic systems also appear to play a role in contributing *E. coli* loads, especially in the subwatersheds surrounding Gaston and Alexandria. Finally, the subwatershed that drains to SR13 is home to one CAFO and 3 of the 4 CFOs in the Pipe Creek watershed. It is estimated that almost 23% of the *E. coli* load in the subwatershed is associated with the CAFO and CFOs.

Table 6-7. Existing Condition *E. coli* Loads within Pipe Creek Subwatersheds

Source Category	CR 600W	CR 900N	CR 1400N	CR 1100N	CR 200W	CR 500W	SR 128	SR13	Ungaged
Manure Application	3.37E+10	5.15E+10	2.62E+11	5.31E+11	6.23E+12	1.09E+13	5.49E+10	4.14E+12	3.95E+10
Active CAFOs	-------	-------	5.97E+09	-------	-------	-------	-------	1.46E+12	-------
Domestic Animals	3.98E+08	2.26E+09	2.50E+09	2.15E+10	3.75E+11	2.84E+11	6.17E+09	6.67E+10	5.42E+08
NPDES	-------	2.29E+07	1.04E+06	-------	8.84E+08	2.78E+08	1.91E+07	-------	-------
Non-CAFO Livestock	1.31E+09	1.56E+09	8.79E+09	2.06E+10	1.97E+11	3.35E+11	1.49E+09	1.11E+11	1.40E+09
Failing Septic	1.78E+09	1.05E+10	1.10E+10	4.35E+10	9.75E+11	1.01E+12	4.64E+09	2.22E+11	2.45E+09
CSOs	-------	-------	-------	-------	1.50E+11	-------	6.12E+09	-------	-------
Wildlife	2.92E+09	5.02E+09	2.24E+10	5.03E+10	6.30E+11	9.90E+11	6.48E+09	3.68E+11	3.68E+09
Upstream Load	0	5.50E+09	2.41E+09	1.32E+10	5.65E+10	3.23E+11	2.08E+12	6.22E+10	1.12E+12
Subwatershed sum	4.01E+10	7.09E+10	3.13E+11	6.67E+11	8.56E+12	1.35E+13	7.98E+10	6.37E+12	4.76E+10
Cumulative sum	4.01E+10	7.64E+10	3.15E+11	6.80E+11	8.61E+12	1.38E+13	2.16E+12	6.43E+12	1.17E+12

Table 6-8. Source Category Percentages of Existing Condition Loads within Pipe Creek Subwatersheds

Source Category	CR 600W	CR 900N	CR 1400N	CR 1100N	CR 200W	CR 500W	SR 128	SR13	Ungaged
Manure Application	84.1%	67.4%	83.2%	78.1%	72.3%	78.8%	2.5%	64.3%	3.4%
Active CAFOs	-----	-----	1.9%	-----	-----	-----	-----	22.8%	-----
Domestic Animals	1.0%	3.0%	0.8%	3.2%	4.3%	2.0%	0.3%	1.0%	0.05%
NPDES	-----	0.030%	0.0003%	-----	0.010%	0.002%	0.001%	-----	-----
Non-CAFO Livestock	3.3%	2.0%	2.8%	3.0%	2.3%	2.4%	0.1%	1.7%	0.1%
Failing Septic	4.4%	13.8%	3.5%	6.4%	11.3%	7.3%	0.2%	3.4%	0.2%
CSOs	-----	-----	-----	-----	1.7%	-----	0.3%	-----	-----
Wildlife	7.3%	6.6%	7.1%	7.4%	7.3%	7.2%	0.3%	5.7%	0.3%
Upstream Load	-----	7.2%	0.8%	1.9%	0.7%	2.3%	96.3%	1.0%	95.9%
	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

6.2.2 INCREMENTAL WATERSHED SOURCE ALLOCATIONS

In order to meet targeted median *E. coli* loads associated with the “never-to-exceed” water quality standard, the percent reductions specified in Table 6-9 were applied to the existing loads in Table 6-7. In determining the percent reduction magnitudes, those source categories contributing the greatest percentages of the existing loads were addressed first. Similar source categories (e.g. non-CAFO, non-CFO associated livestock and manure application) were commonly assigned the same percent reductions. Significant effort was placed in preserving consistency across subwatersheds in the percent reductions assigned to individual source categories.

The allocation shows that exceptionally high reductions (i.e. 80 - 99%) in *E. coli* loads associated with manure application, free-ranging livestock, and failing septic systems are required across the watershed to achieve the water quality standard. Commensurate reductions in loads associated with domestic animals and wildlife are required in the central portion of the watershed, from Alexandria downstream to Frankton. Reductions in domestic and wildlife-related *E. coli* loadings are approximately 50% and 60%, respectively, throughout the rest of the watershed. The central part of the watershed also requires significant reductions in the contributions from CSO discharges.

Table 6-10 shows the projected distribution of *E. coli* loads for each Duck Creek subwatershed after reduction allocations were established. The same distribution is shown in Table 6-11, but is presented in terms of the percentages from each source category.

Table 6-9. Percent TMDL Load Reductions Applied to Source Categories within each Pipe Creek Subwatershed

Source Category	CR 600W	CR 900N	CR 1400N	CR 1100N	CR 200W	CR 500W	SR 128	SR13	Ungaged
Manure Application	**95%**	**95%**	**86%**	**93%**	**99%**	**99%**	**50%**	**90%**	**90%**
Active CAFOs	------	------	0%	------	------	------	------	**85%**	------
Domestic Animals	**50%**	**50%**	**50%**	**50%**	**95%**	**95%**	**50%**	**50%**	**50%**
NPDES	------	0%	0%	------	0%	0%	0%	------	------
Non-CAFO Livestock	**95%**	**95%**	**86%**	**93%**	**99%**	**99%**	**50%**	**90%**	**90%**
Failing Septic	**80%**	**85%**	**85%**	**85%**	**98%**	**98%**	**50%**	**90%**	**90%**
CSOs	------	------	------	------	**97%**	------	0%	------	------
Wildlife	**60%**	**60%**	**60%**	**60%**	**95%**	**95%**	**60%**	**60%**	**60%**

Table 6-10. Projected Pipe Creek Subwatershed *E. coli* Loads after Load Allocation

Source Category	CR 600W	CR 900N	CR 1400N	CR 1100N	CR 200W	CR 500W	SR 128	SR13	Ungaged
Manure Application	1.69E+09	2.58E+09	3.67E+10	3.72E+10	6.23E+10	1.09E+11	2.75E+10	4.14E+11	3.95E+09
Active CAFOs	------	------	5.97E+09	------	------	------	------	2.20E+11	------
Domestic Animals	1.99E+08	1.13E+09	1.25E+09	1.07E+10	1.87E+10	1.42E+10	3.08E+09	3.33E+10	2.71E+08
NPDES	------	2.29E+07	1.04E+06	------	8.84E+08	2.78E+08	1.91E+07	------	------
Non-CAFO Livestock	6.53E+07	7.80E+07	1.23E+09	1.44E+09	1.97E+09	3.35E+09	7.44E+08	1.11E+10	1.40E+08
Failing Septic	3.55E+08	1.58E+09	1.65E+09	6.52E+09	1.95E+10	2.02E+10	2.32E+09	2.22E+10	2.45E+08
CSOs	------	------	------	------	4.50E+09	------	6.12E+09	------	------
Wildlife	1.17E+09	2.01E+09	8.94E+09	2.01E+10	3.15E+10	4.95E+10	2.59E+09	1.47E+11	1.47E+09
Upstream Load	0	4.76E+08	2.49E+08	2.35E+09	6.52E+09	5.48E+09	3.04E+10	2.09E+09	1.48E+11
Subwatershed Sum	3.47E+09	7.39E+09	5.57E+10	7.60E+10	1.39E+11	1.97E+11	4.23E+10	8.47E+11	6.08E+09
Cumulative Sum	3.47E+09	7.87E+09	5.60E+10	7.83E+10	1.46E+11	2.02E+11	7.27E+10	8.50E+11	1.54E+11
Percent Under Target	-1.0%	-1.9%	-5.9%	-15.4%	-3.6%	-2.5%	-65.9%	-3.0%	-------

Table 6-11. Projected Source Category Percentages of Pipe Creek Subwatershed *E. coli* Loads after Load Allocation

Source Category	CR 600W	CR 900N	CR 1400N	CR 1100N	CR 200W	CR 500W	SR 128	SR13	Ungaged
Manure Application	84.1%	67.4%	83.2%	78.1%	72.3%	78.8%	2.5%	64.3%	3.4%
Active CAFOs	-----	-----	1.9%	-----	-----	-----	-----	22.8%	-----
Domestic Animals	1.0%	3.0%	0.8%	3.2%	4.3%	2.0%	0.3%	1.0%	0.05%
NPDES	-----	0.0%	0.000%	-----	0.0%	0.0%	0.00%	-----	-----
Non-CAFO Livestock	3.3%	2.0%	2.8%	3.0%	2.3%	2.4%	0.07%	1.7%	0.12%
Failing Septic	4.4%	13.8%	3.5%	6.4%	11.3%	7.3%	0.2%	3.4%	0.2%
CSOs	-----	-----	-----	-----	1.7%	-----	0.3%	-----	-----
Wildlife	7.3%	6.6%	7.1%	7.4%	7.3%	7.2%	0.3%	5.7%	0.3%
Upstream Load	-----	7.2%	0.8%	1.9%	0.7%	2.3%	96.3%	1.0%	95.9%
	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

6.2.3 WASTE LOAD ALLOCATIONS (WLAS)

E. coli loads from CAFOs, CFOs, NPDES facilities, and CSOs comprise the WLA component of the TMDL. Summarizing the subwatershed loads from those source categories in Table 6-10 results in the WLA component for each subwatershed. Comparison of those loads with the sum of the same categories from Table 6-7 results in the WLA percent reduction required for each subwatershed. Table 6-12 shows the TMDL allocation components, including the WLA, for each of the Pipe Creek subwatersheds. Table 6-12 also shows the WLA percent reductions required for each subwatershed. For the entire Pipe Creek watershed, a WLA percent reduction of 85.4% is required in order to meet the “never-to-exceed” *E. coli* standard.

Table 6-12. Pipe Creek Median Load and Percent Reduction: TMDL Components

Subwatershed	TMDL Median Load Allocations			Percent Reductions	
	WLA	LA	MOS	WLA	LA
CR 600W	0	3.47E+09	3.51E+08	0.0%	91.3%
CR 900N	2.29E+07	7.37E+09	8.02E+08	0.0%	89.6%
CR 1400N	5.97E+09	4.98E+10	5.95E+09	0.0%	83.8%
CR 1100N	0	7.60E+10	9.26E+09	0.0%	88.6%
CR 200W	5.39E+09	1.34E+11	1.51E+10	96.4%	98.4%
CR 500W	2.78E+08	1.96E+11	2.07E+10	0.0%	98.5%
SR 128	6.14E+09	3.62E+10	2.14E+10	0.0%	50.9%
SR13	2.20E+11	6.28E+11	8.76E+10	85.0%	87.2%
Ungaged	0	6.08E+09	0	0.0%	87.2%
Pipe Creek Watershed	**2.38E+11**	**1.14E+12**	**1.61E+11**	**85.4%**	**95.9%**

6.2.4 LOAD ALLOCATIONS

E. coli loads from application of agricultural manure, domestic pets, non-CAFO and non-CFO related free-ranging livestock, failing septic systems, and wildlife comprise the LA component of the TMDL. Summarizing the subwatershed loads from those source categories in Table 6-10 results in the LA component for each subwatershed. Comparison of those loads with the sum of the same categories from Table 6-7 results in the LA percent reduction required for each subwatershed. Table 6-12 shows the TMDL allocation components, including the LA, for each of the Pipe Creek subwatersheds. Table 6-12 also shows the LA percent reductions required for each subwatershed. For the entire Pipe Creek watershed, a LA percent reduction of 95.9% is required in order to meet the “never-to-exceed” *E. coli* standard.

6.3 KILLBUCK CREEK TMDL

TMDL components were established for each of the twelve Killbuck Creek subwatersheds in Delaware and Madison counties. The watershed includes portions of the cities of Muncie and Anderson and 10 NPDES discharges with a potential for *E. coli* contribution. Because these NPDES facilities contribute a relatively small portion of *E. coli* in the individual subwatersheds, no reductions are required. However, the TMDL does include a targeted reduction for a CAFO facility located in subwatershed CR 700W.

6.3.1 EXISTING CONDITIONS

Table 6-13 shows the estimated existing distribution of *E. coli* loads within each of the Killbuck Creek subwatersheds. The percentages associated with each source category are presented in Table 6-14. Headwater subwatersheds are denoted in yellow. These existing conditions distributions demonstrate that the application of manure to row crops and pasture lands constitutes the largest percentage of *E. coli* loads in the headwater subwatersheds and several of the other subwatersheds, including NCR 925 and CR 700. Septic systems throughout the watershed are also attributed with high *E. coli* loads. No CSOs were included in this analysis of the Killbuck Creek watershed.

Table 6-13. Existing *E. coli* Loads within Killbuck Creek Subwatersheds

Source Category	Mud Creek	Killbuck Headwaters	SR 28/ US 35	CR 700W	CR 750W	NCR 925W
Manure Application	5.53E+10	1.33E+11	6.03E+11	4.40E+11	5.89E+11	4.23E+11
Active CAFOs	0	0	0	7.01E+10	0	0
Domestic Animals	3.35E+09	2.16E+09	4.22E+10	6.11E+10	1.27E+11	2.33E+09
NPDES	2.04E+06	0	0	0	4.74E+06	8.16E+06
Non-CAFO Livestock	2.56E+09	5.05E+09	4.13E+10	4.84E+10	9.36E+10	4.60E+10
Failing Septic	1.42E+10	3.19E+10	5.56E+10	8.23E+10	1.31E+11	2.82E+10
CSOs	0	0	0	0	0	0
Wildlife	4.96E+09	1.42E+10	5.30E+10	4.79E+10	5.51E+10	4.67E+10
Upstream Load	0	0	1.70E+10	9.65E+10	0	2.02E+11
Subwatershed Sum	8.04E+10	1.86E+11	7.95E+11	7.50E+11	9.95E+11	5.46E+11
Cumulative Sum	8.04E+10	1.86E+11	8.12E+11	8.46E+11	9.95E+11	7.49E+11

Source Category	SR 332	CR 425E	CR 400N	Little Killbuck Creek	SR 9 Bridge	Broadway St.
Manure Application	6.07E+11	2.13E+11	2.55E+11	2.05E+11	3.70E+11	7.89E+11
Active CAFOs	0	0	0	0	0	0
Domestic Animals	1.77E+09	6.16E+09	1.54E+09	3.51E+10	1.81E+10	1.17E+10
NPDES	0	0	2.06E+06	1.32E+06	0	3.03E+06
Non-CAFO Livestock	2.40E+10	2.28E+10	2.07E+10	4.68E+10	5.66E+10	1.24E+11
Failing Septic	2.80E+10	1.51E+10	1.27E+10	1.46E+11	2.73E+11	1.26E+11
CSOs	0	0	0	0	0	0
Wildlife	1.73E+10	3.10E+10	9.39E+09	1.24E+11	1.02E+11	4.15E+10
Upstream Load	0	1.33E+11	3.57E+10	0	1.08E+11	1.38E+11
Subwatershed Sum	6.78E+11	2.88E+11	3.00E+11	5.57E+11	8.19E+11	1.09E+12
Cumulative Sum	6.78E+11	4.21E+11	3.35E+11	5.57E+11	9.28E+11	1.23E+12

Table 6-14. Source Category Percentages of Existing Condition Loads within Killbuck Creek Subwatersheds

Source Category	Mud Creek	Killbuck Headwaters	SR 28/ US 35	CR 700W	CR 750W	NCR 925W
Manure Application	68.8%	71.3%	74.3%	52.0%	59.2%	56.5%
Active CAFOs	-----	-----	-----	8.3%	-----	-----
Domestic Animals	4.2%	1.2%	5.2%	7.2%	12.8%	0.3%
NPDES	0.0%	-----	-----	-----	0.0%	0.0%
Non-CAFO Livestock	3.2%	2.7%	5.1%	5.7%	9.4%	6.1%
Failing Septic	17.6%	17.2%	6.8%	9.7%	13.1%	3.8%
CSOs	-----	-----	-----	-----	-----	-----
Wildlife	6.2%	7.6%	6.5%	5.7%	5.5%	6.2%
Upstream Load	-----	-----	2.1%	11.4%	-----	27.0%
	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

Source Category	SR 332	CR 425E	CR 400N	Little Killbuck Creek	SR 9 Bridge	Broadway St.
Manure Application	89.5%	50.5%	76.1%	36.8%	39.9%	64.1%
Active CAFOs	-----	-----	-----	-----	-----	-----
Domestic Animals	0.3%	1.5%	0.5%	6.3%	2.0%	0.9%
NPDES	-----	-----	0.0%	0.0%	-----	0.0%
Non-CAFO Livestock	3.5%	5.4%	6.2%	8.4%	6.1%	10.1%
Failing Septic	4.1%	3.6%	3.8%	26.3%	29.4%	10.2%
CSOs	-----	-----	-----	-----	-----	-----
Wildlife	2.6%	7.4%	2.8%	22.2%	11.0%	3.4%
Upstream Load	-----	31.7%	10.7%	-----	11.7%	11.2%
	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

6.3.2 INCREMENTAL WATERSHED SOURCE ALLOCATIONS

In order to meet targeted median *E. coli* loads associated with the “never-to-exceed” water quality standard, the percent reductions specified in Table 6-15 were applied to the existing loads in Table 6-13. In determining the percent reduction magnitudes, those source categories contributing the greatest percentages of the existing loads were addressed first. Similar source categories (e.g. non-CFO associated livestock and manure application) were commonly assigned the same percent reductions. Considerable effort was placed in preserving consistency across subwatersheds in the percent reductions assigned to individual source categories.

The allocation shows that high reductions (i.e. 60 - 99%) in *E. coli* loads associated with manure application, free-ranging livestock, and failing septic systems are required across the watershed to achieve the water quality standard. Reductions in loads associated with domestic animals and wildlife are also relatively high (70 – 98%) throughout the watershed.

Table 6-16 shows the projected distribution of *E. coli* loads for each Killbuck Creek subwatershed after reduction allocations were established. The same distribution is shown in Table 6-17, but is presented in terms of the percentages from each source category.

Table 6-15. Percent TMDL Load Reductions Applied to Source Categories within each Killbuck Creek Subwatershed

Source Category	Mud Creek	Killbuck Headwaters	SR 28/ US 35	CR 700W	CR 750W	NCR 925W
Manure Application	**0%**	**98%**	**91%**	**60%**	**92%**	**63%**
Active CAFOs	**------**	**------**	**------**	**60%**	**------**	**------**
Domestic Animals	**0%**	**98%**	**91%**	**60%**	**92%**	**63%**
NPDES	0%	**------**	**------**	**------**	0%	0%
Non-CAFO Livestock	**0%**	**98%**	**91%**	**60%**	**92%**	**63%**
Failing Septic	**0%**	**95%**	**80%**	**65%**	**90%**	**60%**
CSOs	**------**	**------**	**------**	**------**	**------**	**------**
Wildlife	**0%**	**98%**	**91%**	**60%**	**85%**	**60%**

Source Category	SR 332	CR 425E	CR 400N	Little Killbuck Creek	SR 9 Bridge	Broadway St.
Manure Application	**92%**	**90%**	**90%**	**99%**	**70%**	**66%**
Active CAFOs	**------**	**------**	**------**	**------**	**------**	**------**
Domestic Animals	**92%**	**90%**	**70%**	**91%**	**70%**	**66%**
NPDES	**------**	**------**	0%	0%	**------**	0%
Non-CAFO Livestock	**92%**	**90%**	**90%**	**99%**	**70%**	**66%**
Failing Septic	**90%**	**90%**	**85%**	**99%**	**70%**	**66%**
CSOs	**------**	**------**	**------**	**------**	**------**	**------**
Wildlife	**70%**	**85%**	**80%**	**95%**	**70%**	**55%**

Table 6-16. Projected Killbuck Creek Subwatershed *E. coli* Loads after Load Allocation

Source Category	Mud Creek	Killbuck Headwaters	SR 28/ US 35	CR 700W	CR 750W	NCR 925W
Manure Application	5.53E+10	2.65E+09	5.43E+10	1.76E+11	4.71E+10	1.57E+11
Active CAFOs	------	------	------	2.80E+10	------	------
Domestic Animals	3.35E+09	4.32E+07	3.80E+09	2.44E+10	1.02E+10	8.61E+08
NPDES	2.04E+06	------	------	------	4.74E+06	8.16E+06
Non-CAFO Livestock	2.56E+09	1.01E+08	3.72E+09	1.94E+10	7.49E+09	1.70E+10
Failing Septic	1.42E+10	1.60E+09	1.11E+10	2.88E+10	1.31E+10	1.13E+10
CSOs	------	------	------	------	------	------
Wildlife	4.96E+09	2.84E+08	4.77E+09	1.92E+10	8.27E+09	1.87E+10
Upstream Load	0	0	6.07E+09	9.95E+09	0	1.14E+10
Subwatershed sum	8.04E+10	4.68E+09	7.77E+10	2.96E+11	8.61E+10	2.04E+11
Cumulative sum	8.04E+10	4.68E+09	8.38E+10	3.06E+11	8.61E+10	2.16E+11
Percent Under Target	0.0%	-2.5%	-2.5%	-0.9%	-1.8%	-0.5%

Source Category	SR 332	CR 425E	CR 400N	Little Killbuck Creek	SR 9 Bridge	Broadway St.
Manure Application	4.85E+10	2.13E+10	2.55E+10	2.05E+09	1.11E+11	2.68E+11
Active CAFOs	------	------	------	------	------	------
Domestic Animals	1.41E+08	6.16E+08	4.61E+08	3.15E+09	5.44E+09	3.97E+09
NPDES	------	------	2.06E+06	1.32E+06	------	3.03E+06
Non-CAFO Livestock	1.92E+09	2.28E+09	2.07E+09	4.68E+08	1.70E+10	4.21E+10
Failing Septic	2.80E+09	1.51E+09	1.91E+09	1.46E+09	8.18E+10	4.27E+10
CSOs	------	------	------	------	------	------
Wildlife	5.20E+09	4.65E+09	1.88E+09	6.18E+09	3.05E+10	1.87E+10
Upstream Load	0	6.13E+09	3.10E+09	0	1.97E+09	3.69E+10
Subwatershed sum	5.86E+10	3.03E+10	3.18E+10	1.33E+10	2.46E+11	3.76E+11
Cumulative sum	5.86E+10	3.64E+10	3.49E+10	1.33E+10	2.48E+11	4.13E+11
Percent Under Target	-1.9%	-1.8%	-1.5%	-1.6%	-2.7%	-3.2%

Table 6-17. Projected Source Category Percentages of Killbuck Creek Subwatershed *E. coli* Loads after Load Allocation

Source Category	Mud Creek	Killbuck Headwaters	SR 28/ US 35	CR 700W	CR 750W	NCR 925W
Manure Application	68.8%	56.7%	64.8%	57.6%	54.7%	72.5%
Active CAFOs	------	------	------	9.2%	------	------
Domestic Animals	4.2%	0.9%	4.5%	8.0%	11.8%	0.4%
NPDES	0.003%	------	------	------	0.006%	0.004%
Non-CAFO Livestock	3.2%	2.2%	4.4%	6.3%	8.7%	7.9%
Failing Septic	17.6%	34.1%	13.3%	9.4%	15.2%	5.2%
CSOs	------	------	------	------	------	------
Wildlife	6.2%	6.1%	5.7%	6.3%	9.6%	8.7%
Upstream Load	0.0%	0.0%	7.2%	3.3%	0.0%	5.3%
	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

Source Category	SR 332	CR 425E	CR 400N	Little Killbuck Creek	SR 9 Bridge	Broadway St.
Manure Application	82.8%	58.3%	73.1%	15.4%	44.8%	65.0%
Active CAFOs	-----	-----	-----	-----	-----	-----
Domestic Animals	0.2%	1.7%	1.3%	23.7%	2.2%	1.0%
NPDES	-----	-----	0.006%	0.010%	-----	0.001%
Non-CAFO Livestock	3.3%	6.2%	5.9%	3.5%	6.8%	10.2%
Failing Septic	4.8%	4.2%	5.5%	11.0%	33.0%	10.3%
CSOs	-----	-----	-----	-----	-----	-----
Wildlife	8.9%	12.8%	5.4%	46.4%	12.3%	4.5%
Upstream Load	0.0%	16.8%	8.9%	0.0%	0.8%	9.0%
	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

6.3.3 WASTE LOAD ALLOCATIONS (WLAS)

E. coli loads from CFOs, NPDES facilities, and CSOs comprise the WLA component of the TMDL. Summarizing the subwatershed loads from those source categories in Table 6-18 results in the WLA component for each subwatershed. Comparison of those loads with the sum of the same categories from Table 6-13 results in the WLA percent reduction required for each subwatershed. Table 6-18 shows the TMDL allocation components, including the WLA, for each of the Killbuck Creek subwatersheds. For Killbuck Creek, there are no CSOs and the *E. coli* load from the single CFO in subwatershed CR 700W is three to four orders of magnitude greater than the total of all watershed NPDES *E. coli* loads. Hence, the 60% reduction applied to the CFO essentially represents all of the WLA reduction in Killbuck Creek. Table 6-18 also shows the WLA percent reductions required for each subwatershed. For the entire Killbuck Creek watershed, the 60% reduction applied in CR 700W also represents the total watershed reduction of 60% that is required in order to meet the "never-to-exceed" *E. coli* standard.

Table 6-18. Killbuck Creek Median Load and Percent Reduction: TMDL Components

Subwatershed	TMDL Median Load Allocations			Percent Reductions	
	WLA	LA	MOS	WLA	LA
Mud Creek	2.04E+06	8.04E+10	8.04E+09	0.0%	0.0%
Killbuck Headwaters	0	4.68E+09	4.80E+08	0.0%	97.5%
SR 28/US 35	0	7.77E+10	8.59E+09	0.0%	90.2%
CR 700W	2.80E+10	2.68E+11	3.09E+10	60.0%	60.6%
CR 750W	4.74E+06	8.61E+10	8.77E+09	0.0%	91.4%
NCR 925W	8.16E+06	2.04E+11	2.17E+10	0.0%	62.6%
SR 332	0	5.86E+10	5.97E+09	0.0%	91.4%
CR 425E	0	3.03E+10	3.71E+09	0.0%	89.5%
CR 400N	2.06E+06	3.18E+10	3.55E+09	0.0%	89.4%
Little Killbuck Creek	1.32E+06	1.33E+10	1.35E+09	0.0%	97.6%
SR 9 Bridge	0	2.46E+11	2.55E+10	0.0%	70.0%
Broadway St.	3.03E+06	3.76E+11	4.26E+10	0.0%	65.6%
Killbuck Creek Watershed	**2.81E+10**	**1.48E+12**	**1.61E+11**	**60.0%**	**79.0%**

6.3.4 LOAD ALLOCATIONS

E. coli loads from application of agricultural manure, domestic pets, non-CFO related free-ranging livestock, failing septic systems, and wildlife comprise the LA component of the TMDL. Summarizing the subwatershed loads from those source categories in Table 6-16 results in the LA component for each subwatershed. Comparison of those loads with the sum of the same categories from Table 6-13 results in the LA percent reduction required for each subwatershed. Table 6-18 shows the TMDL allocation components, including the LA, for each of the Killbuck Creek subwatersheds. Table 6-18 also shows the LA percent reductions required for each subwatershed. For the entire Killbuck Creek watershed, a LA percent reduction of 79% is required in order to meet the “never-to-exceed” *E. coli* standard.

6.4 STONY CREEK TMDL

The Stony Creek watershed contains seventeen subwatersheds, including the entirety of the Lapel community, a small portion of Anderson, and a portion of Noblesville. CSOs attributed to Noblesville represent a significant source of *E. coli* loads to the North Trib at 166th Street - Noblesville subwatershed. Two NPDES dischargers and two active CFO facilities contribute to the existing *E. coli* load in the overall watershed. The relative contributions from the CFO facilities required a high reduction (i.e. $\geq$ 90%).

6.4.1 EXISTING CONDITIONS

Table 6-19 shows the estimated existing distribution of *E. coli* loads within each of the seventeen Stony Creek subwatersheds. The percentages associated with each source category are presented in Table 6-20. Headwater subwatersheds are denoted in yellow. These existing condition distributions demonstrate that the application of manure to row crops and pasture lands constitutes the largest percentage of *E. coli* loads in the majority of the subwatersheds. The relative percentages tend to decline slightly in the lower reaches of the watershed, where more urban-associated source categories contribute more. The extent of *E. coli* loads related to domestic pets increases in the 166th St Noblesville and Allisonville Rd subwatersheds, which contain portions of the Noblesville community and its associated higher population and domestic pet densities. The two CFOs in the watershed and the CSOs in Noblesville also contribute significant sources (i.e. 10 – 20%) of the *E. coli* load in their respective subwatersheds.

6.4.2 INCREMENTAL WATERSHED SOURCE ALLOCATIONS

In order to meet targeted median *E. coli* loads associated with the “never-to-exceed” water quality standard, the percent reductions specified in Table 6-21 were applied to the existing loads in Table 6-19. In determining the percent reduction magnitudes, those source categories contributing the greatest percentages of the existing loads were addressed first. Similar source categories (e.g. non-CFO associated livestock and manure application) were commonly assigned the same percent reductions. Considerable effort was placed in preserving consistency across subwatersheds in the percent reductions assigned to individual source categories.

Table 6-19. Existing Condition *E. coli* Loads within Stony Creek Subwatersheds

Source Category	CR 650 W	CR 825 W	CR 925 W	SR 132/13	CR 1000 W	Cyntheanne Rd	Stony Creek at 70026	E 206th St near Durbin Rd	William Lock Ditch
Manure Application	6.16E+10	1.47E+11	5.05E+11	3.20E+11	6.30E+11	5.11E+11	5.20E+11	3.15E+11	2.49E+11
Active CAFOs	0	0	1.57E+11	0	0	0	0	4.51E+10	0
Domestic Animals	1.40E+09	1.60E+09	1.83E+10	1.90E+11	5.42E+10	1.18E+10	7.69E+09	4.62E+09	3.50E+09
NPDES	0	0	0	2.25E+09	4.42E+07	0	1.22E+07	0	0
Non-CAFO Livestock	6.41E+09	1.25E+10	4.07E+10	2.58E+10	3.44E+10	4.07E+10	2.68E+10	7.80E+09	1.08E+10
Failing Septic	5.70E+09	7.35E+09	3.04E+10	9.33E+10	4.77E+10	4.11E+10	3.48E+10	2.06E+10	1.56E+10
CSOs	0	0	0	0	0	0	0	0	0
Wildlife	5.24E+09	1.26E+10	4.38E+10	8.50E+10	6.11E+10	5.64E+10	4.72E+10	2.80E+10	2.15E+10
Upstream Load	0	4.58E+09	1.60E+10	1.29E+11	1.67E+11	8.81E+10	4.13E+10	0	3.45E+10
Subwatershed Sum	8.04E+10	1.81E+11	7.96E+11	7.16E+11	8.28E+11	6.61E+11	6.36E+11	4.21E+11	3.01E+11
Cumulative Sum	8.04E+10	1.86E+11	8.12E+11	8.46E+11	9.95E+11	7.49E+11	6.78E+11	4.21E+11	3.35E+11

Source Category	E 196th St	166th St.	Private dr off SR 38	SR 38	Union Chapel Rd	Cumberland Rd Gaging Station	166th St. Noblesville	Allisonville Rd.
Manure Application	3.35E+11	7.21E+11	8.22E+11	5.41E+10	1.46E+11	1.50E+11	5.33E+10	4.45E+10
Active CAFOs	0	0	0	0	0	0	0	0
Domestic Animals	5.28E+09	1.18E+10	5.01E+10	5.72E+09	1.01E+10	2.54E+09	2.01E+10	9.42E+09
NPDES	0	0	0	0	0	0	2.66E+05	0
Non-CAFO Livestock	2.23E+10	5.19E+10	7.91E+10	9.35E+09	1.28E+10	1.36E+10	2.92E+09	4.87E+09
Failing Septic	2.40E+10	7.71E+10	5.72E+10	1.28E+10	1.51E+10	1.06E+11	1.19E+10	3.02E+10
CSOs	0	0	0	0	0	0	1.35E+10	0
Wildlife	2.91E+10	6.55E+10	8.68E+10	4.91E+09	1.27E+10	1.33E+10	6.34E+09	5.38E+09
Upstream Load	1.41E+11	0	1.35E+11	3.78E+11	2.97E+10	2.13E+10	0	1.71E+10
Subwatershed Sum	4.15E+11	9.27E+11	1.09E+12	8.69E+10	1.96E+11	2.86E+11	1.08E+11	9.44E+10
Cumulative Sum	5.57E+11	9.27E+11	1.23E+12	4.65E+11	2.26E+11	3.07E+11	1.08E+11	1.11E+11

The allocation shows that high reductions (65 – 92%) in *E. coli* loads associated with manure application and free-ranging livestock are required across the watershed to achieve the water quality standard. Relatively high reductions (60 – 90%) in loads associated with failing septic systems, wildlife, and domestic animals are also required across the watershed. 90% reductions are required from both CFOs in the watershed and a 77% reduction from the Noblesville CSOs, coupled with equivalent percent reductions from the other source categories in the North Trib subwatershed, will ensure the *E. coli* single sample standard is achieved there.

Table 6-22 shows the projected distribution of *E. coli* loads for each Stony Creek subwatershed after reduction allocations were established. The same distribution is shown in Table 6-23, but is presented in terms of the percentages from each source category.

Table 6-20. Source Category Percentages of Existing Condition Loads within Stony Creek Subwatersheds

Source Category	CR 650 W	CR 825 W	CR 925 W	SR 132/13	CR 1000 W	Cyntheanne Rd	Stony Creek at 70026	E 206th St near Durbin Rd	William Lock Ditch
Manure Application	76.7%	79.2%	62.3%	37.9%	63.3%	68.2%	76.7%	74.8%	74.4%
Active CAFOs	-----	-----	19.3%	-----	-----	-----	-----	10.7%	-----
Domestic Animals	1.7%	0.9%	2.3%	22.4%	5.5%	1.6%	1.1%	1.1%	1.0%
NPDES	-----	-----	-----	0.3%	0.0%	-----	0.0%	-----	-----
Non-CAFO Livestock	8.0%	6.7%	5.0%	3.1%	3.5%	5.4%	4.0%	1.9%	3.2%
Failing Septic	7.1%	3.9%	3.7%	11.0%	4.8%	5.5%	5.1%	4.9%	4.7%
CSOs	-----	-----	-----	-----	-----	-----	-----	-----	-----
Wildlife	6.5%	6.8%	5.4%	10.1%	6.1%	7.5%	7.0%	6.7%	6.4%
Upstream Load	-----	2.5%	2.0%	15.3%	16.8%	11.8%	6.1%	-----	10.3%
	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

Source Category	E 196th St	166th St.	Private dr off SR 38	SR 38	Union Chapel Rd	Cumberland Rd Gaging Station	166th St. Noblesville	Allisonville Rd.
Manure Application	60.1%	77.8%	66.8%	11.6%	64.4%	49.0%	49.3%	39.9%
Active CAFOs	-----	-----	-----	-----	-----	-----	-----	-----
Domestic Animals	0.9%	1.3%	4.1%	1.2%	4.5%	0.8%	18.6%	8.5%
NPDES	-----	-----	-----	-----	-----	-----	0.0%	-----
Non-CAFO Livestock	4.0%	5.6%	6.4%	2.0%	5.7%	4.4%	2.7%	4.4%
Failing Septic	4.3%	8.3%	4.6%	2.8%	6.7%	34.5%	11.0%	27.1%
CSOs	-----	-----	-----	-----	-----	-----	12.5%	-----
Wildlife	5.2%	7.1%	7.1%	1.1%	5.6%	4.3%	5.9%	4.8%
Upstream Load	25.4%	-----	11.0%	81.3%	13.1%	6.9%	-----	15.3%
	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

Table 6-21. Percent TMDL Load Reductions Applied to Source Categories within Each Stony Creek Subwatershed

Source Category	CR 650 W	CR 825 W	CR 925 W	SR 132/13	CR 1000 W	Cyntheanne Rd	Stony Creek at 70026	E 206th St near Durbin Rd	William Lock Ditch
Manure Application	**65%**	**81%**	**92%**	**92%**	**92%**	**88%**	**85%**	**92%**	**85%**
Active CAFOs	------	------	**92%**	------	------	------	------	**90%**	------
Domestic Animals	**60%**	**60%**	**85%**	**92%**	**92%**	**88%**	**80%**	**92%**	**80%**
NPDES	------	------	------	0%	0%	------	0%	------	------
Non-CAFO Livestock	**60%**	**81%**	**92%**	**92%**	**92%**	**88%**	**85%**	**90%**	**85%**
Failing Septic	**60%**	**60%**	**85%**	**90%**	**85%**	**80%**	**85%**	**85%**	**65%**
CSOs	------	------	------	------	------	------	------	------	------
Wildlife	**60%**	**65%**	**90%**	**90%**	**90%**	**85%**	**85%**	**90%**	**75%**

Source Category	E 196th St	166th St.	Private dr off SR 38	SR 38	Union Chapel Rd	Cumberland Rd Gaging Station	166th St. Noblesville	Allisonville Rd.
Manure Application	**65%**	**81%**	**92%**	**92%**	**92%**	**88%**	**85%**	**92%**
Active CAFOs	------	------	------	------	------	------	------	------
Domestic Animals	**60%**	**60%**	**85%**	**92%**	**92%**	**88%**	**80%**	**92%**
NPDES	------	------	------	------	------	------	0%	------
Non-CAFO Livestock	**60%**	**81%**	**92%**	**92%**	**92%**	**88%**	**85%**	**90%**
Failing Septic	**60%**	**60%**	**85%**	**90%**	**85%**	**80%**	**85%**	**85%**
CSOs	------	------	------	------	------	------	------	------
Wildlife	**60%**	**65%**	**90%**	**90%**	**90%**	**85%**	**85%**	**90%**

6.4.3 WASTE LOAD ALLOCATIONS (WLAs)

E. coli loads from CFOs, NPDES facilities, and CSOs comprise the WLA component of the TMDL. Summarizing the subwatershed loads from those source categories in Table 6-22 results in the WLA component for each subwatershed. Comparison of those loads with the sum of the same categories from Table 6-19 results in the WLA percent reduction required for each subwatershed. Table 6-24 shows the TMDL allocation components, including the WLA, for each of the Stony Creek subwatersheds. Table 6-24 also shows the WLA percent reductions required for each subwatershed. For the entire Stony Creek watershed, a WLA percent reduction of 89.7% is required in order to meet the “never-to-exceed” *E. coli* standard.

Table 6-22. Projected Stony Creek Subwatershed *E. coli* Loads after Load Allocation

Source Category	CR 650 W	CR 825 W	CR 925 W	SR 132/13	CR 1000 W	Cyntheanne Rd	Stony Creek at 70026	E 206th St near Durbin Rd	William Lock Ditch
Manure Application	2.16E+10	2.80E+10	4.04E+10	2.56E+10	5.04E+10	6.13E+10	7.80E+10	2.52E+10	3.74E+10
Active CAFOs	------	------	1.26E+10	------	------	------	------	4.51E+09	------
Domestic Animals	5.61E+08	6.38E+08	2.74E+09	1.52E+10	4.34E+09	1.42E+09	1.54E+09	3.69E+08	6.99E+08
NPDES	------	------	------	2.25E+09	4.42E+07	------	1.22E+07	------	------
Non-CAFO Livestock	2.56E+09	2.38E+09	3.26E+09	2.06E+09	2.75E+09	4.88E+09	4.02E+09	7.80E+08	1.62E+09
Failing Septic	2.28E+09	2.94E+09	4.56E+09	9.33E+09	7.16E+09	8.21E+09	5.22E+09	3.08E+09	5.45E+09
CSOs	------	------	------	------	------	------	------	------	------
Wildlife	2.09E+09	4.43E+09	4.38E+09	8.50E+09	6.11E+09	8.46E+09	7.08E+09	2.80E+09	5.36E+09
Upstream Load	0	1.66E+09	3.44E+09	1.14E+10	1.47E+10	7.58E+09	5.07E+09	0	3.01E+09
Subwatershed Sum	2.91E+10	3.84E+10	6.80E+10	6.29E+10	7.08E+10	8.43E+10	9.59E+10	3.67E+10	5.05E+10
Cumulative Sum	2.91E+10	4.00E+10	7.14E+10	7.43E+10	8.55E+10	9.19E+10	1.01E+11	3.67E+10	5.35E+10
Percent Under Target	-0.82%	-0.28%	-0.20%	-0.27%	-2.47%	-1.42%	-1.43%	-0.98%	-1.79%

Source Category	E 196th St	166th St.	Private dr off SR 38	SR 38	Union Chapel Rd	Cumberland Rd Gaging Station	166th St. Noblesville	Allisonville Rd.
Manure Application	2.68E+10	7.21E+10	8.22E+10	4.33E+09	1.17E+10	3.76E+10	1.22E+10	4.45E+09
Active CAFOs	------	------	------	------	------	------	------	------
Domestic Animals	4.22E+08	1.18E+09	5.01E+09	4.58E+08	8.06E+08	6.36E+08	4.62E+09	9.42E+08
NPDES	------	------	------	------	------	------	2.66E+05	------
Non-CAFO Livestock	1.79E+09	5.19E+09	7.91E+09	7.48E+08	1.02E+09	3.40E+09	6.72E+08	4.87E+08
Failing Septic	1.92E+09	1.16E+10	8.58E+09	1.03E+09	1.51E+09	3.17E+10	2.73E+09	6.04E+09
CSOs	------	------	------	------	------	------	3.09E+09	------
Wildlife	5.82E+09	6.55E+09	1.30E+10	3.93E+08	1.27E+09	4.00E+09	1.46E+09	1.61E+09
Upstream Load	2.17E+10	0	1.16E+10	4.20E+10	3.12E+09	1.83E+09	0	1.69E+10
Subwatershed Sum	3.67E+10	9.66E+10	1.17E+11	6.95E+09	1.63E+10	7.73E+10	2.48E+10	1.35E+10
Cumulative Sum	5.84E+10	9.66E+10	1.28E+11	4.89E+10	1.94E+10	7.92E+10	2.48E+10	3.04E+10
Percent Under Target	-0.8%	-1.5%	-1.4%	-0.5%	-2.7%	0.0%	0.0%	-0.7%

Table 6-23. Projected Source Category Percentages of Stony Creek Subwatershed *E. coli* Loads after Load Allocation

Source Category	CR 650 W	CR 825 W	CR 925 W	SR 132/13	CR 1000 W	Cyntheanne Rd	Stony Creek at 70026	E 206th St near Durbin Rd	William Lock Ditch
Manure Application	74.2%	69.9%	56.6%	34.5%	59.0%	66.7%	77.3%	68.6%	69.8%
Active CAFOs	------	------	17.6%	------	------	------	------	12.3%	------
Domestic Animals	1.9%	1.6%	3.8%	20.4%	5.1%	1.5%	1.5%	1.0%	1.3%
NPDES	------	------	------	3.0%	0.05%	------	0.01%	------	------
Non-CAFO Livestock	8.8%	5.9%	4.6%	2.8%	3.2%	5.3%	4.0%	2.1%	3.0%
Failing Septic	7.8%	7.3%	6.4%	12.6%	8.4%	8.9%	5.2%	8.4%	10.2%
CSOs	------	------	------	------	------	------	------	------	------
Wildlife	7.2%	11.1%	6.1%	11.4%	7.1%	9.2%	7.0%	7.6%	10.0%
Upstream Load	-----	4.1%	4.8%	15.3%	17.2%	8.2%	5.0%	-----	5.6%
	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

Source Category	E 196th St	166th St.	Private dr off SR 38	SR 38	Union Chapel Rd	Cumberland Rd Gaging Station	166th St. Noblesville	Allisonville Rd.
Manure Application	45.8%	74.7%	64.1%	8.8%	60.1%	47.5%	49.3%	14.6%
Active CAFOs	-----	-----	-----	-----	-----	-----	-----	-----
Domestic Animals	0.7%	1.2%	3.9%	0.9%	4.2%	0.8%	18.6%	3.1%
NPDES	-----	-----	-----	-----	-----	-----	0.001%	-----
Non-CAFO Livestock	3.1%	5.4%	6.2%	1.5%	5.3%	4.3%	2.7%	1.6%
Failing Septic	3.3%	12.0%	6.7%	2.1%	7.8%	40.1%	11.0%	19.9%
CSOs	-----	-----	-----	-----	-----	-----	12.5%	-----
Wildlife	10.0%	6.8%	10.2%	0.8%	6.6%	5.0%	5.9%	5.3%
Upstream Load	37.1%	-----	9.0%	85.8%	16.1%	2.3%	-----	55.5%
	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

Table 6-24. Stony Creek Median Load and Percent Reduction: TMDL Components

	TMDL Median Load Allocations			Percent Reductions	
Subwatershed	WLA	LA	MOS	WLA	LA
CR 650 W	0	2.91E+10	2.93E+09	0.0%	63.8%
CR 825 W	0	3.84E+10	4.01E+09	0.0%	78.8%
CR 925 W	1.26E+10	5.54E+10	7.15E+09	92.0%	91.3%
SR 132/13	2.25E+09	6.07E+10	7.45E+09	0.0%	91.5%
CR 1000 W	4.42E+07	7.08E+10	8.77E+09	0.0%	91.4%
Cyntheanne Rd	0	8.43E+10	9.32E+09	0.0%	87.2%
Stony Creek at 70026	1.22E+07	9.59E+10	1.02E+10	0.0%	84.9%
E 206th St near Durbin Rd	4.51E+09	3.22E+10	3.71E+09	90.0%	91.4%
William Lock Ditch	0	5.05E+10	5.45E+09	0.0%	83.2%
E 196th St	0	3.67E+10	5.89E+09	0.0%	91.2%
166th St.	0	9.66E+10	9.81E+09	0.0%	89.6%
private dr off SR 38	0	1.17E+11	1.30E+10	0.0%	89.3%
SR 38	0	6.95E+09	4.92E+09	0.0%	92.0%
Union Chapel Rd	0	1.63E+10	1.99E+09	0.0%	91.7%
Cumberland Rd Gaging Station	0	7.73E+10	7.91E+09	0.0%	72.9%
166th St. Noblesville	3.09E+09	2.17E+10	2.48E+09	77.0%	77.0%
Allisonville Rd.	0	1.35E+10	3.06E+09	0.0%	85.7%
Stony Creek Watershed	**2.25E+10**	**9.03E+11**	**1.08E+11**	**89.7%**	**88.1%**

6.4.4 LOAD ALLOCATIONS

E. coli loads from application of agricultural manure, domestic pets, non-CFO related free-ranging livestock, failing septic systems, and wildlife comprise the LA component of the TMDL.

Summarizing the subwatershed loads from those source categories in Table 6-22 results in the LA component for each subwatershed. Comparison of those loads with the sum of the same categories from Table 6-19 results in the LA percent reduction required for each subwatershed. Table 6-24 shows the TMDL allocation components, including the LA, for each of the Stony Creek subwatersheds. Table 6-24 also shows the LA percent reductions required for each subwatershed. For the entire Stony Creek watershed, a LA percent reduction of 88.1% is required in order to meet the "never-to-exceed" *E. coli* standard.

6.5 COMPREHENSIVE ASSESSMENT

The *E. coli* load percent reductions for the WLA and LA components of the Duck Creek, Pipe Creek, Killbuck Creek, and Stony Creek TMDLs are shown in Tables 6-6, 6-12, 6-18, and 6-24, respectively. The LA reductions, which range from 79% (Killbuck Creek) to 95.9% (Pipe Creek), are not unexpected, especially with the large amounts of agriculture manure generated and applied, the incidences of failing septic systems, and the stout populations of certain wildlife species in the watersheds. The variability in the percentages is somewhat curious, especially given the relatively consistent distributions of nonpoint sources in the four watersheds. Much of this variability can be explained by the limitations associated with the available monitoring data at each of the sampling sites. Most of the sites have no more than five *E. coli* samples associated with them, with many having fewer than five. As discussed in Section 5, the maximum observed concentrations were used to characterize the existing water quality conditions at each station. The inherent variability of the *E. coli* indicator is such that maximum observed values at some stations were close to an order of magnitude greater than at other stations. As additional samples are collected at each station, the probability of observing a high concentration increases, and the LA reductions required would become less variable.

The variability in the WLA reductions is even more striking, with Killbuck Creek at 60%, and the other 3 watersheds in a more consistent range between 85.4 and 94.6%. While this variability is more dramatic, it is actually much easier to understand why that occurs. In the Killbuck Creek watershed, there is only one point source of consequence, a CFO in the CR 700W subwatershed. The estimated existing *E. coli* load from that CFO is 3 orders of magnitude greater than the sum of the ten NPDES loads in the watershed. For the CR 700W subwatershed, percent reductions of 60-65% were specified for each of the other source categories. At this level of reduction for the nonpoint sources, a commensurate 60% reduction from the CFO was required in order to meet the *E. coli* single sample standard in the subwatershed.

The high WLA percent reduction required for Duck Creek is also understandable, given the existence and previous performance of the CSOs in the City of Elwood. For the Duck Creek subwatersheds where these CSOs are located, which are relatively small, the percent reductions required from the CSOs are 96 - 98%. These individual subwatershed percent reductions tend to boost the overall watershed number to its current level.

7.0 MARGIN OF SAFETY

The Margin of Safety (MOS) is a required component of a TMDL that accounts for the uncertainty in the linkage between the sources and the receiving water quality. The MOS is often included implicitly into conservative assumptions that are used to develop the TMDL. Alternatively, the MOS may be explicitly identified as a percentage of the TMDL or as a separate load quantity (USEPA, 1991).

For the Duck Creek, Pipe Creek, Killbuck Creek, and Stony Creek TMDLs, an explicit MOS of 10% is incorporated into the TMDL. This value is defined to account for any uncertainty associated with estimates of existing loads, spatial distribution of land uses and soils, instream *E. coli* decay rates, and achievable load reduction efficiencies of the referenced management practices. When applied to the Indiana single-sample E.coli standard of 235 CFU / 100 mL, the 10% MOS value corresponds to that loading which would account for instream E.coli concentrations of 23.5 CFU / 100 mL. Accordingly, the allowable E.coli load for each assessment location corresponds to that which would result in instream concentrations of 211.5 CFU / 100 mL.

8.0 SEASONAL VARIABILITY

Seasonality in the TMDL is addressed by expressing the TMDL in terms of the *E. coli* WQS for total body contact during the recreational season (April 1^{st} through October 31^{st}) as defined by 327 IAC 2-1-6(d). There is no applicable total body contact *E. coli* WQS during the remainder of the year in Indiana. Because this is a concentration-based TMDL, *E. coli* WQS will be met regardless of flow conditions in the applicable season.

9.0 PUBLIC PARTICIPATION

All TMDLs are conducted with input from the general public. This input is typically provided via stakeholder meetings held within the watersheds. An initial kickoff stakeholder meeting for the Duck Creek, Pipe Creek, Killbuck Creek, and Stony Creek TMDLs was held on August 25, 2004 at the Anderson Public Library, 111 East 12th Street, Anderson, IN. During that meeting, IDEM personnel described the Indiana TMDL Program, discussed the specific reasons why TMDLs are being performed in the four watersheds, identified specific water quality and public health concerns regarding *E. coli*, and distributed a questionnaire to attendees to help identify additional sources of data that could be instrumental to the TMDLs.

A second public meeting is planned for Spring 2005 to present the draft TMDL report. Written public comments will only be accepted for a period of 30 days following release of the draft report.

10.0 REASONABLE ASSURANCE

The TMDLs established for Duck Creek, Pipe Creek, Killbuck Creek, and Stony Creek show that significant reductions in *E. coli* are required in each watershed in order to meet water quality standards. The most significant sources of *E. coli* include activities associated with the agricultural application of manure, livestock (CAFO, CFO, and other), failing septic systems, wildlife, domestic animals, and CSOs. Reasonable assurance activities are programs that are in place or will be in place to assist in meeting the Duck Creek, Pipe Creek, Killbuck Creek, and Stony Creek watershed TMDL allocations and the *E. coli* Water Quality Standard (WQS).

Confined Feeding Operations and Confined Animal Feeding Operations.

CFOs and CAFOs are required to manage manure, litter, process wastewater pollutants in a manner that does not cause or contribute to the impairment of *E. coli* WQS.

CSO Long Term Control Plans.

Indiana's existing strategy for addressing CSO compliance, via each community's Long Term Control Plan (LTCP), is expected to reduce loadings from those sources. The percent reductions associated with CSOs in these TMDLs essentially provide targeted goals for the subject LTCPs.

Existing Watershed Projects.

The White River Watershed Project is conducting a focused assessment of the Killbuck Creek/Mud Creek subwatershed. The major goals of the Killbuck/Mud Creek subwatershed project are to (1) identify all existing and failing on-site septic systems in the study area so that septic waste from those locations will be included in an ongoing sewer project, (2) identify all existing and failing agricultural drainage tiles, so that repair of the tiles can be efficiently addressed by the owners, (3) identify all existing and potential agricultural conservation practices that may be applied in the watershed, (4) establish better quantifications of the bacterial loadings from geese in the watershed, and (5) provided public outreach information, via paper maps and media outlets, regarding the sources of pollutant loadings in the watershed. This project will help to further identify and reduce specific nonpoint sources that are contributing to the *E. coli* impairment in the Killbuck Creek watershed.

The Madison County SWCD used funds from an EPA Section 319 Grant to provide public outreach for information and prevention of nonpoint source pollution. The grant was administered through IDEM and the main projects of the grant were:

1) Creation of a watershed management plan for a 14 digit HUC (Hydrologic Unit Code) watershed within Madison County.

2) Replacement of 4 failed conventional septic systems with 4 new alternative septic systems.

3) Education for the residents of Madison County about nonpoint source pollution and how to prevent it. A specific component was included to educate the public regarding the maintenance of existing conventional septic systems so as to increase the life expectancy of those systems, thus preventing failed systems from contributing to water quality problems.

This project contributed to actual E.coli load reductions (via replacement of the four septic systems) and well as to the potential for future reductions (via the public outreach component and watershed management plan).

Potential Future Activities:

Nonpoint source pollution, which is the primary cause of E. coli impairment in this watershed, can be reduced by the implementation of "best management practices" (BMPs). BMPs are practices used in agriculture, forestry, urban land development, and industry to reduce the potential for damage to natural resources from human activities. A BMP may be structural, that is, something that is built or involves changes in landforms or equipment, or it may be managerial, that is, a specific way of using or handling infrastructure or resources. BMPs should be selected based on the goals of a watershed management plan. Livestock owners, farmers, and urban planners, can implement BMPs outside of a watershed management plan, but the success of BMPs would be enhanced if coordinated as part of a watershed management plan. Following are examples of BMPs that may be used to reduce *E. coli* runoff:

Adherence to Documented Manure Application Rates. There is a litany of state and federal guidance available for determining appropriate manure application rates. These rates typically vary with the types of animals contributing the waste, the types of crops to be cultivated, and soil characteristics. In Indiana, the Purdue University Cooperative Extension Service is a readily available resource for this type of information. Other federal or interstate sources include the Midwest Plan Service, which has published its Livestock Waste Facilities Handbook (MWPS, 1993). Other documents, such as the USEPA's CAFO Manure Management guide (USEPA, 2004) and the Comprehensive Nutrient Management Plan section of the National Planning Procedures Handbook (USDA-NRCS, 2000) also provide guidance on appropriate manure application rates.

No-Till Farming. No-till is a year-round conservation farming system. In its pure form, no-till does not include any tillage operations either before or after planting. The practice reduces wind and water erosion, catches snow, conserves soil and water, protects water quality, and provides wildlife habitat. No-till helps control soil erosion and improve water quality by maintaining maximum residue plant levels on the soil surface. These plant residues: 1) protect soil particles and applied nutrients and pesticides from detachment by wind and water; 2) increase infiltration; and 3) reduce the speed at which wind and water move over the soil surface.

Establishment of Centralized Composting Facilities. Farmers in many agricultural regions, especially those with high densities of CAFO, CFO, and other livestock facilities, have considered creating centralized composting facilities, where farmers can bring excess manure to be composted and subsequently sold to smaller operations or other users. Other potential users might include state Departments of Transportation or construction firms that perform significant levels of landscaping. Composted manure from a centralized facility can provide an excellent topsoil supplement for these activities.

Livestock Exclusion. For CAFO, CFO, and other livestock operations, a concerted effort should be made to exclude livestock from riparian areas. This is typically implemented via fencing and the provision of alternative water sources for the otherwise free-ranging animals. With significant percentages of pasture land acreages adjacent to receiving waters in the Duck Creek, Pipe Creek, Killbuck Creek, and Stony Creek watersheds, limitation of livestock access to these areas will reduce the levels of *E. coli* that are directly deposited into those surface waters. Excluding these animals from the riparian zone also provides the additional benefit of allowing re-establishment of vegetation roots in the zone, which will mitigate streambank erosion and provide additional filtering for any *E. coli* laden runoff that does make it to the stream.

Septic System Public Outreach. Many homeowners may not know when their septic systems are failing. This is particularly true for those owners whose leach fields may be intermingling with agricultural tile drains in the areas. Other homeowners may know about the septic failure, but choose not to address it due to the expense. A public outreach program should be implemented to inform residents about the potential for septic system failure in the region, with a specific focus on understanding the potential for tile drain/leach field interference. The public outreach program should also include instructions on how to identify the characteristics of a septic system, how to recognize when it is failing, what regular maintenance should be performed, and what options exist for sewage disposal. The public outreach program should also incorporate a water quality component to make residents aware of the potential negative impacts that failing systems can have.

Septic System Maintenance/Elimination. A concerted effort should also be made to identify and repair/replace failing septic systems. Residents in each of the watershed counties should be required to have their systems inspected regularly and pumped out, if necessary. Many of the homeowners in the study area may require financial assistance to address their septic system issues. A publicly-funded program to address failing septic systems could help to reduce *E. coli* loads from the sources in each of the watersheds. Funds from this program could be used to help defray the costs of site inspections and system repairs. Where possible, the funds could also be used to connect individual residences to sewered systems.

Public Outreach to Domestic Animal Owners. An information program to educate residents about the potential for pathogen loads from their pets should be implemented, especially in the urban and suburban communities within the four watersheds. The program should include information about the benefits of cleaning up after pets. Each of the communities in the Duck Creek, Pipe Creek, Killbuck Creek, and Stony Creek watersheds should also endeavor to enforce existing codes regarding local leash laws and should establish or increase fines associated with violations of those laws.

Wildlife Population Control Measures. Education programs should be established throughout the watershed communities regarding the contributions that wildlife make to bacterial loadings in the local receiving streams. The education program should describe the conditions that provide desirable habitats for deer, raccoon, and Canadian geese and encourage municipal officials, landowners and farmers to avoid creating those conditions. Reductions in the deer and raccoon population may also be pursued through increases in the number of deer hunting licenses allowed and providing additional financial incentives for the trapping of raccoons in the region.

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APPENDIX A

WATER QUALITY DATA

Duck Creek Watershed – *E. coli* data

STATION	DATE	DESCRIPTION	SOURCE	E.COLI MF	GEO. MEAN
WWU060-0001	2/20/1996	CR 1300 N, Fairground Rd	IDEM	10	
WWU060-0001	4/22/1996	CR 1300 N, Fairground Rd	IDEM	1200	
WWU060-0001	5/29/1996	CR 1300 N, Fairground Rd	IDEM	40	
WWU060-0001	7/9/1996	CR 1300 N, Fairground Rd	IDEM	280	
WWU060-0001	10/1/1996	CR 1300 N, Fairground Rd	IDEM	100	
WWU060-0001	11/12/1996	CR 1300 N, Fairground Rd	IDEM	470	
WWU060-0001	4/23/2001	CR 1300 N, Fairground Rd	IDEM	340	
WWU060-0001	4/30/2001	CR 1300 N, Fairground Rd	IDEM	250	
WWU060-0001	5/7/2001	CR 1300 N, Fairground Rd	IDEM	200	
WWU060-0001	5/14/2001	CR 1300 N, Fairground Rd	IDEM	150	
WWU060-0001	5/21/2001	CR 1300 N, Fairground Rd	IDEM	330	243
WWU060-0003	2/20/1996	SR 213, D/S Side	IDEM	10	
WWU060-0003	4/22/1996	SR 213, D/S Side	IDEM	1600	
WWU060-0003	5/29/1996	SR 213, D/S Side	IDEM	600	
WWU060-0003	7/9/1996	SR 213, D/S Side	IDEM	40	
WWU060-0003	10/1/1996	SR 213, D/S Side	IDEM	150	
WWU060-0003	11/12/1996	SR 213, D/S Side	IDEM	380	
WWU060-0003	4/23/2001	SR 213, D/S Side	IDEM	480	
WWU060-0003	4/30/2001	SR 213, D/S Side	IDEM	220	
WWU060-0003	5/7/2001	SR 213, D/S Side	IDEM	460	
WWU060-0003	5/14/2001	SR 213, D/S Side	IDEM	440	
WWU060-0003	5/21/2001	SR 213, D/S Side	IDEM	1300	
WWU060-0003	6/4/2001	SR 213, D/S Side	IDEM	921	
WWU060-0003	6/11/2001	SR 213, D/S Side	IDEM	921	
WWU060-0003	6/18/2001	SR 213, D/S Side	IDEM	921	
WWU060-0003	6/25/2001	SR 213, D/S Side	IDEM	517	
WWU060-0003	7/2/2001	SR 213, D/S Side	IDEM	1046	760
WWU060-0009	4/23/2001	Hwy 28	IDEM	410	
WWU060-0009	4/23/2001	Hwy 28	IDEM	340	
WWU060-0009	4/30/2001	Hwy 28	IDEM	25	
WWU060-0009	4/30/2001	Hwy 28	IDEM	100	
WWU060-0009	5/7/2001	Hwy 28	IDEM	2	
WWU060-0009	5/7/2001	Hwy 28	IDEM	180	
WWU060-0009	5/14/2001	Hwy 28	IDEM	1400	
WWU060-0009	5/21/2001	Hwy 28	IDEM	1700	153
WWU060-0010	4/23/2001	CR 1400 N	IDEM	230	
WWU060-0010	4/30/2001	CR 1400 N	IDEM	79	
WWU060-0010	5/7/2001	CR 1400 N	IDEM	450	
WWU060-0010	5/14/2001	CR 1400 N	IDEM	84	
WWU060-0010	5/21/2001	CR 1400 N	IDEM	260	178

Duck Creek Watershed – *E. coli* data

STATION	DATE	DESCRIPTION	SOURCE	E.COLI MF	GEO. MEAN
WWU060-0011	4/23/2001	CR 1400 N	IDEM	520	
WWU060-0011	4/30/2001	CR 1400 N	IDEM	140	
WWU060-0011	5/7/2001	CR 1400 N	IDEM	180	
WWU060-0011	5/14/2001	CR 1400 N	IDEM	290	
WWU060-0011	5/21/2001	CR 1400 N	IDEM	450	280
WWU060-0012	4/23/2001	CR 1400 N	IDEM	2400	
WWU060-0012	4/30/2001	S 9th St (Elwood)	IDEM	240	
WWU060-0012	5/7/2001	S 9th St (Elwood)	IDEM	1100	
WWU060-0012	5/14/2001	S 9th St (Elwood)	IDEM	2000	
WWU060-0012	5/21/2001	S 9th St (Elwood)	IDEM	10000	
WWU060-0012	5/21/2001	S 9th St (Elwood)	IDEM	8200	2125
WWU060-0013	4/23/2001	Elwood WWTP Effluent	IDEM	2400	
WWU060-0013	4/30/2001	Elwood WWTP Effluent	IDEM	730	
WWU060-0013	5/7/2001	Elwood WWTP Effluent	IDEM	2	
WWU060-0013	5/14/2001	Elwood WWTP Effluent	IDEM	10	
WWU060-0013	5/21/2001	Elwood WWTP Effluent	IDEM	9200	200
WWU060-0014	4/23/2001	CR 1050 N	IDEM	1300	
WWU060-0014	4/30/2001	CR 1050 N	IDEM	2	
WWU060-0014	5/7/2001	CR 1050 N	IDEM	2	
WWU060-0014	5/14/2001	CR 1050 N	IDEM	1300	
WWU060-0014	5/21/2001	CR 1050 N	IDEM	3900	121
WWU060-0015	4/23/2001	CR 900 W	IDEM	2000	
WWU060-0015	4/30/2001	CR 900 W	IDEM	220	
WWU060-0015	5/7/2001	CR 900 W	IDEM	2	
WWU060-0015	5/14/2001	CR 900 W	IDEM	2	
WWU060-0015	5/21/2001	CR 900 W	IDEM	4400	95
WWU060-0016	4/23/2001	CR 1000 N	IDEM	1000	
WWU060-0016	4/30/2001	CR 1000 N	IDEM	160	
WWU060-0016	5/7/2001	CR 1000 N	IDEM	2	
WWU060-0016	5/14/2001	CR 1000 N	IDEM	1400	
WWU060-0016	5/21/2001	CR 1000 N	IDEM	2900	265
WWU060-0017	4/23/2001	CR 800 E	IDEM	1600	
WWU060-0017	4/30/2001	CR 800 E	IDEM	2	
WWU060-0017	5/7/2001	CR 800 E	IDEM	200	
WWU060-0017	5/14/2001	CR 800 E	IDEM	660	
WWU060-0017	5/21/2001	CR 800 E	IDEM	410	177
WWU060-0018	4/23/2001	CR 900 N	IDEM	2	
WWU060-0018	4/30/2001	CR 900 N	IDEM	920	
WWU060-0018	5/7/2001	CR 900 N	IDEM	1000	
WWU060-0018	5/14/2001	CR 900 N	IDEM	1200	

Duck Creek Watershed – *E. coli* data

STATION	DATE	DESCRIPTION	SOURCE	E.COLI MF	GEO. MEAN
WWU060-0018	5/21/2001	CR 900 N	IDEM	1700	327
WWU060-0019	4/23/2001	Hayworth Rd (Gunn Rd) (CR 700 E)	IDEM	690	
WWU060-0019	4/30/2001	Hayworth Rd (Gunn Rd) (CR 700 E)	IDEM	920	
WWU060-0019	5/7/2001	Hayworth Rd (Gunn Rd) (CR 700 E)	IDEM	440	
WWU060-0019	5/14/2001	Hayworth Rd (Gunn Rd) (CR 700 E)	IDEM	1300	
WWU060-0019	5/14/2001	Hayworth Rd (Gunn Rd) (CR 700 E)	IDEM	1600	
WWU060-0019	5/21/2001	Hayworth Rd (Gunn Rd) (CR 700 E)	IDEM	1100	985
WWU060-0020	4/23/2001	E 246th St, (CR 300 N)	IDEM	870	
WWU060-0020	4/30/2001	E 246th St, (CR 300 N)	IDEM	240	
WWU060-0020	5/7/2001	E 246th St, (CR 300 N)	IDEM	520	
WWU060-0020	5/14/2001	E 246th St, (CR 300 N)	IDEM	870	
WWU060-0020	5/21/2001	E 246th St, (CR 300 N)	IDEM	3300	792
WWU060-0021	4/23/2001	Henry Gunn Rd	IDEM	2400	
WWU060-0021	4/30/2001	Henry Gunn Rd	IDEM	2400	
WWU060-0021	5/7/2001	Henry Gunn Rd	IDEM	370	
WWU060-0021	5/14/2001	Henry Gunn Rd	IDEM	5500	
WWU060-0021	5/21/2001	Henry Gunn Rd	IDEM	4600	2220
WWU060-0022	8/6/1996	20th St	IDEM	390	

Pipe Creek Watershed – *E. coli* data

STATION	DATE	DESCRIPTION	SOURCE	E.COLI MF	GEO. MEAN
WWU050-0003	2/20/1996	SR 13	1996 Synoptic	20	
WWU050-0003	4/24/1996	SR 13	1996 Synoptic	2800	
WWU050-0003	5/31/1996	SR 13	1996 Synoptic	600	
WWU050-0003	7/9/1996	SR 13	1996 Synoptic	330	
WWU050-0003	10/2/1996	SR 13	1996 Synoptic	420	
WWU050-0003	11/14/1996	SR 13	1996 Synoptic	4800	
WWU050-0003	6/4/2001	SR 13	2001 W Fk White River in Hamilton Co Assessment	770	
WWU050-0003	6/5/2001	SR 13	2001 Pipe Creek TMDL	649	
WWU050-0003	6/11/2001	SR 13	2001 W Fk White River in Hamilton Co Assessment	816	
WWU050-0003	6/12/2001	SR 13	2001 Pipe Creek TMDL	1553	
WWU050-0003	6/18/2001	SR 13	2001 W Fk White River in Hamilton Co Assessment	866	
WWU050-0003	6/19/2001	SR 13	2001 Pipe Creek TMDL	727	
WWU050-0003	6/25/2001	SR 13	2001 W Fk White River in Hamilton Co Assessment	727	
WWU050-0003	6/26/2001	SR 13	2001 Pipe Creek TMDL	579	
WWU050-0003	6/26/2001	SR 13	2001 Pipe Creek TMDL	649	
WWU050-0003	7/2/2001	SR 13	2001 WFWR in Hamilton Co	517	
WWU050-0003	7/3/2001	SR 13	2001 Pipe Creek TMDL	308	692
WWU050-0005	6/5/2001	CR 500 W , NE of Frankton (Madison Co)	2001 Pipe Creek TMDL	2	
WWU050-0005	6/12/2001	CR 500 W , NE of Frankton (Madison Co)	2001 Pipe Creek TMDL	14136	
WWU050-0005	6/19/2001	CR 500 W , NE of Frankton (Madison Co)	2001 Pipe Creek TMDL	2282	
WWU050-0005	6/26/2001	CR 500 W , NE of Frankton (Madison Co)	2001 Pipe Creek TMDL	1414	
WWU050-0005	7/3/2001	CR 500 W , NE of Frankton (Madison Co)	2001 Pipe Creek TMDL	461	531
WWU050-0012	8/6/1996	CR 200 W	1996 Watershed	400	
WWU050-0013	6/5/2001	CR 200 W	2001 Pipe Creek TMDL	2	
WWU050-0013	6/12/2001	CR 200 W	2001 Pipe Creek TMDL	179	
WWU050-0013	6/19/2001	CR 200 W	2001 Pipe Creek TMDL	2142	
WWU050-0013	6/26/2001	CR 200 W	2001 Pipe Creek TMDL	1414	
WWU050-0013	7/3/2001	CR 200 W	2001 Pipe Creek TMDL	365	
WWU050-0013	7/3/2001	CR 200 W	2001 Pipe Creek TMDL	488	240
WWU050-0014	6/5/2001	CR 200 W	2001 Pipe Creek TMDL	2	
WWU050-0014	6/12/2001	CR 200 W	2001 Pipe Creek TMDL	12033	
WWU050-0014	6/19/2001	CR 200 W	2001 Pipe Creek TMDL	1120	
WWU050-0014	6/19/2001	CR 200 W	2001 Pipe Creek TMDL	1300	
WWU050-0014	6/26/2001	CR 200 W	2001 Pipe Creek TMDL	687	
WWU050-0014	7/3/2001	CR 200 W	2001 Pipe Creek TMDL	291	437
WWU050-0015	6/5/2001	CR 1100 N (Bethel Rd)	2001 Pipe Creek TMDL	770	
WWU050-0015	6/12/2001	CR 1100 N (Bethel Rd)	2001 Pipe Creek TMDL	1553	
WWU050-0015	6/19/2001	CR 1100 N (Bethel Rd)	2001 Pipe Creek TMDL	517	
WWU050-0015	6/26/2001	CR 1100 N (Bethel Rd)	2001 Pipe Creek TMDL	461	

Pipe Creek Watershed – *E. coli* data

STATION	DATE	DESCRIPTION	SOURCE	E.COLI MF	GEO. MEAN
WWU050-0015	7/3/2001	CR 1100 N (Bethel Rd)	2001 Pipe Creek TMDL	816	638
WWU050-0016	6/5/2001	CR 1400 N	2001 Pipe Creek TMDL	727	
WWU050-0016	6/12/2001	CR 1400 N	2001 Pipe Creek TMDL	387	
WWU050-0016	6/19/2001	CR 1400 N	2001 Pipe Creek TMDL	461	
WWU050-0016	6/26/2001	CR 1400 N	2001 Pipe Creek TMDL	1046	
WWU050-0016	7/3/2001	CR 1400 N	2001 Pipe Creek TMDL	1120	686
WWU050-0017	6/5/2001	CR 900 N	2001 Pipe Creek TMDL	1120	
WWU050-0017	6/12/2001	CR 900 N	2001 Pipe Creek TMDL	2	
WWU050-0017	6/12/2001	CR 900 N	2001 Pipe Creek TMDL	2	
WWU050-0017	6/19/2001	CR 900 N	2001 Pipe Creek TMDL	579	
WWU050-0017	6/26/2001	CR 900 N	2001 Pipe Creek TMDL	2014	
WWU050-0017	7/3/2001	CR 900 N	2001 Pipe Creek TMDL	167	98
WWU050-0018	6/5/2001	CR 600 W	2001 Pipe Creek TMDL	435	
WWU050-0018	6/12/2001	CR 600 W	2001 Pipe Creek TMDL	1203	
WWU050-0018	6/19/2001	CR 600 W	2001 Pipe Creek TMDL	2419	
WWU050-0018	6/26/2001	CR 600 W	2001 Pipe Creek TMDL	1733	
WWU050-0018	7/3/2001	CR 600 W	2001 Pipe Creek TMDL	1733	1306

Killbuck Creek Watershed – *E. coli* data

STATION	DATE	DESCRIPTION	SOURCE	E.COLI MF	GEO. MEAN
WWU040-0001	4/24/2001	SR 9 Bridge, NE Side of Anderson	2001 Killbuck Creek TMDL	96	
WWU040-0001	5/1/2001	SR 9 Bridge, NE Side of Anderson	2001 Killbuck Creek TMDL	160	
WWU040-0001	5/8/2001	SR 9 Bridge, NE Side of Anderson	2001 Killbuck Creek TMDL	770	
WWU040-0001	5/15/2001	SR 9 Bridge, NE Side of Anderson	2001 Killbuck Creek TMDL	100	
WWU040-0001	5/22/2001	SR 9 Bridge, NE Side of Anderson	2001 Killbuck Creek TMDL	280	266
WWU040-0012	4/24/2001	Grand Ave, Anderson	2001 WFWR in Madison County	100	
WWU040-0012	5/1/2001	Grand Ave, Anderson	2001 WFWR in Madison County	170	
WWU040-0012	5/8/2001	Grand Ave, Anderson	2001 WFWR in Madison County	1000	
WWU040-0012	5/15/2001	Grand Ave, Anderson	2001 WFWR in Madison County	280	
WWU040-0012	5/22/2001	Grand Ave, Anderson	2001 WFWR in Madison County	210	251
WWU040-0018	4/24/2001	Broadway St (Jackson St)	2001 Killbuck Creek TMDL	96	
WWU040-0018	5/1/2001	Broadway St (Jackson St)	2001 Killbuck Creek TMDL	200	
WWU040-0018	5/8/2001	Broadway St (Jackson St)	2001 Killbuck Creek TMDL	610	
WWU040-0018	5/15/2001	Broadway St (Jackson St)	2001 Killbuck Creek TMDL	200	
WWU040-0018	5/15/2001	Broadway St (Jackson St)	2001 Killbuck Creek TMDL	210	218
WWU040-0018	5/22/2001	Broadway St (Jackson St)	2001 Killbuck Creek TMDL	300	
WWU040-0018	5/22/2001	Broadway St (Jackson St)	2001 Killbuck Creek TMDL	290	
WWU040-0019	4/24/2001	CR 400 N	2001 Killbuck Creek TMDL	340	
WWU040-0019	5/1/2001	CR 400 N	2001 Killbuck Creek TMDL	490	
WWU040-0019	5/8/2001	CR 400 N	2001 Killbuck Creek TMDL	8700	
WWU040-0019	5/15/2001	CR 400 N	2001 Killbuck Creek TMDL	580	
WWU040-0019	5/22/2001	CR 400 N	2001 Killbuck Creek TMDL	330	774
WWU040-0020	4/24/2001	CR 400 N	2001 Killbuck Creek TMDL	210	
WWU040-0020	5/1/2001	CR 400 N	2001 Killbuck Creek TMDL	110	
WWU040-0020	5/8/2001	CR 400 N	2001 Killbuck Creek TMDL	2000	
WWU040-0020	5/15/2001	CR 400 N	2001 Killbuck Creek TMDL	29	
WWU040-0020	5/22/2001	CR 400 N	2001 Killbuck Creek TMDL	240	200
WWU040-0021	4/24/2001	CR 425 E	2001 Killbuck Creek TMDL	260	
WWU040-0021	4/24/2001	CR 425 E	2001 Killbuck Creek TMDL	310	
WWU040-0021	5/1/2001	CR 425 E	2001 Killbuck Creek TMDL	170	
WWU040-0021	5/8/2001	CR 425 E	2001 Killbuck Creek TMDL	2400	
WWU040-0021	5/15/2001	CR 425 E	2001 Killbuck Creek TMDL	870	
WWU040-0021	5/22/2001	CR 425 E	2001 Killbuck Creek TMDL	400	475
WWU040-0022	4/24/2001	SR 332	2001 Killbuck Creek TMDL	520	
WWU040-0022	5/1/2001	SR 332	2001 Killbuck Creek TMDL	370	
WWU040-0022	5/8/2001	SR 332	2001 Killbuck Creek TMDL	2400	
WWU040-0022	5/15/2001	SR 332	2001 Killbuck Creek TMDL	870	
WWU040-0022	5/22/2001	SR 332	2001 Killbuck Creek TMDL	550	739
WWU040-0023	4/24/2001	NCR 925 W	2001 Killbuck Creek TMDL	580	
WWU040-0023	5/1/2001	NCR 925 W	2001 Killbuck Creek TMDL	490	

Killbuck Creek Watershed – *E. coli* data

STATION	DATE	DESCRIPTION	SOURCE	E.COLI MF	GEO. MEAN
WWU040-0023	5/8/2001	NCR 925 W	2001 Killbuck Creek TMDL	2	
WWU040-0023	5/15/2001	NCR 925 W	2001 Killbuck Creek TMDL	730	
WWU040-0023	5/22/2001	NCR 925 W	2001 Killbuck Creek TMDL	440	179
WWU040-0024	4/24/2001	CR 750 W	2001 Killbuck Creek TMDL	690	
WWU040-0024	5/1/2001	CR 750 W	2001 Killbuck Creek TMDL	2400	
WWU040-0024	5/8/2001	CR 750 W	2001 Killbuck Creek TMDL	2	
WWU040-0024	5/15/2001	CR 750 W	2001 Killbuck Creek TMDL	2	
WWU040-0024	5/22/2001	CR 750 W	2001 Killbuck Creek TMDL	330	74
WWU040-0025	4/24/2001	CR 700 W	2001 Killbuck Creek TMDL	410	
WWU040-0025	5/1/2001	CR 700 W	2001 Killbuck Creek TMDL	170	
WWU040-0025	5/1/2001	CR 700 W	2001 Killbuck Creek TMDL	110	
WWU040-0025	5/8/2001	CR 700 W	2001 Killbuck Creek TMDL	580	
WWU040-0025	5/15/2001	CR 700 W	2001 Killbuck Creek TMDL	410	
WWU040-0025	5/22/2001	CR 700 W	2001 Killbuck Creek TMDL	520	313
WWU040-0026	4/24/2001	SR 28 / US 35	2001 Killbuck Creek TMDL	2000	
WWU040-0026	5/1/2001	SR 28 / US 35	2001 Killbuck Creek TMDL	310	
WWU040-0026	5/8/2001	SR 28 / US 35	2001 Killbuck Creek TMDL	580	
WWU040-0026	5/15/2001	SR 28 / US 35	2001 Killbuck Creek TMDL	390	
WWU040-0026	5/22/2001	SR 28 / US 35	2001 Killbuck Creek TMDL	260	516
WWU040-0027	4/24/2001	SR 28 / US 35	2001 Killbuck Creek TMDL	2	
WWU040-0027	5/1/2001	SR 28 / US 35	2001 Killbuck Creek TMDL	2	
WWU040-0027	5/8/2001	SR 28 / US 35	2001 Killbuck Creek TMDL	8200	
WWU040-0027	5/8/2001	SR 28 / US 35	2001 Killbuck Creek TMDL	1100	
WWU040-0027	5/15/2001	SR 28 / US 35	2001 Killbuck Creek TMDL	550	
WWU040-0027	5/22/2001	SR 28 / US 35	2001 Killbuck Creek TMDL	180	124
WWU040-0028	4/24/2001	CR 200 W	2001 Killbuck Creek TMDL	190	
WWU040-0028	5/1/2001	CR 200 W	2001 Killbuck Creek TMDL	11	
WWU040-0028	5/8/2001	CR 200 W	2001 Killbuck Creek TMDL	91	
WWU040-0028	5/15/2001	CR 200 W	2001 Killbuck Creek TMDL	54	
WWU040-0028	5/22/2001	CR 200 W	2001 Killbuck Creek TMDL	160	70
K-1	7/23/2002	Wheeling Avenue Bridge	Upper White River Watershed Project	5500	
K-1	10/17/2002	Wheeling Avenue Bridge	Upper White River Watershed Project	1130	
K-1	5/1/2003	Wheeling Avenue Bridge	Upper White River Watershed Project	640	
K-1	5/5/2003	Wheeling Avenue Bridge	Upper White River Watershed Project	9600	
K-1	5/8/2003	Wheeling Avenue Bridge	Upper White River Watershed Project	1070	
K-1	5/15/2003	Wheeling Avenue Bridge	Upper White River Watershed Project	11000	
K-1	5/22/2003	Wheeling Avenue Bridge	Upper White River Watershed Project	762	
K-1	5/29/2003	Wheeling Avenue Bridge	Upper White River Watershed Project	3900	
K-1	7/23/2003	Wheeling Avenue Bridge	Upper White River Watershed Project	772	
K-1	9/3/2003	Wheeling Avenue Bridge	Upper White River Watershed Project	6700	

Killbuck Creek Watershed – *E. coli* data

STATION	DATE	DESCRIPTION	SOURCE	E.COLI MF	GEO. MEAN
K-1	10/14/2003	Wheeling Avenue Bridge	Upper White River Watershed Project	833	
K-1	4/29/2004	Wheeling Avenue Bridge	Upper White River Watershed Project	146	
K-2	7/23/2002	SR 28 Bridge	Upper White River Watershed Project	1110	
K-2	10/15/2002	SR 28 Bridge	Upper White River Watershed Project	470	
K-2	5/1/2003	SR 28 Bridge	Upper White River Watershed Project	1370	
K-2	5/5/2003	SR 28 Bridge	Upper White River Watershed Project	11300	
K-2	5/8/2003	SR 28 Bridge	Upper White River Watershed Project	2640	
K-2	5/22/2003	SR 28 Bridge	Upper White River Watershed Project	1270	
K-2	5/29/2003	SR 28 Bridge	Upper White River Watershed Project	5700	
K-2	7/23/2003	SR 28 Bridge	Upper White River Watershed Project	667	
K-2	9/3/2003	SR 28 Bridge	Upper White River Watershed Project	10700	
K-2	10/14/2003	SR 28 Bridge	Upper White River Watershed Project	1300	
K-2	4/29/2004	SR 28 Bridge	Upper White River Watershed Project	152	
K-3	7/23/2002	CR 25 West Bridge	Upper White River Watershed Project	1060	
K-3	10/15/2002	CR 25 West Bridge	Upper White River Watershed Project	1100	
K-3	5/1/2003	CR 25 West Bridge	Upper White River Watershed Project	1630	
K-3	5/5/2003	CR 25 West Bridge	Upper White River Watershed Project	4540	
K-3	5/8/2003	CR 25 West Bridge	Upper White River Watershed Project	2400	

Stony Creek Watershed – *E. coli* data

STATION	DATE	DESCRIPTION	SOURCE	E.COLI MF	GEO. MEAN
WWU070-0002	2/22/1996	Cumberland Rd, Gaging Station	IDEM	1	
WWU070-0002	4/24/1996	Cumberland Rd, Gaging Station	IDEM	1600	
WWU070-0002	6/4/1996	Cumberland Rd, Gaging Station	IDEM	220	
WWU070-0002	7/11/1996	Cumberland Rd, Gaging Station	IDEM	170	
WWU070-0002	10/3/1996	Cumberland Rd, Gaging Station	IDEM	800	
WWU070-0002	11/14/1996	Cumberland Rd, Gaging Station	IDEM	70	
WWU070-0002	6/5/2001	Cumberland Rd, Gaging Station	IDEM	770	
WWU070-0002	6/12/2001	Cumberland Rd, Gaging Station	IDEM	650	
WWU070-0002	6/19/2001	Cumberland Rd, Gaging Station	IDEM	820	
WWU070-0002	6/26/2001	Cumberland Rd, Gaging Station	IDEM	610	
WWU070-0002	7/3/2001	Cumberland Rd, Gaging Station	IDEM	310	600
WWU070-0016	6/4/2001	Allisonville Road	IDEM	1046	
WWU070-0016	6/5/2001	Allisonville Road	IDEM	770	
WWU070-0016	6/11/2001	Allisonville Road	IDEM	148	
WWU070-0016	6/12/2001	Allisonville Road	IDEM	370	
WWU070-0016	6/18/2001	Allisonville Road	IDEM	727	
WWU070-0016	6/18/2001	Allisonville Road	IDEM	770	
WWU070-0016	6/19/2001	Allisonville Road	IDEM	440	
WWU070-0016	6/25/2001	Allisonville Road	IDEM	4	
WWU070-0016	6/26/2001	Allisonville Road	IDEM	410	
WWU070-0016	7/2/2001	Allisonville Road	IDEM	816	
WWU070-0016	7/3/2001	Allisonville Road	IDEM	410	
WWU070-0016	7/3/2001	Allisonville Road	IDEM	410	308
WWU070-0018	6/5/2001	166th St. Noblesville	IDEM	280	
WWU070-0018	6/12/2001	166th St. Noblesville	IDEM	520	
WWU070-0018	6/19/2001	166th St. Noblesville	IDEM	270	
WWU070-0018	6/26/2001	166th St. Noblesville	IDEM	920	
WWU070-0018	7/3/2001	166th St. Noblesville	IDEM	730	483
WWU070-0019	6/5/2001	Union Chapel Rd	IDEM	2400	
WWU070-0019	6/12/2001	Union Chapel Rd	IDEM	1100	
WWU070-0019	6/19/2001	Union Chapel Rd	IDEM	1200	
WWU070-0019	6/26/2001	Union Chapel Rd	IDEM	310	
WWU070-0019	7/3/2001	Union Chapel Rd	IDEM	820	958
WWU070-0020	6/5/2001	166th St.	IDEM	650	
WWU070-0020	6/12/2001	166th St.	IDEM	240	
WWU070-0020	6/19/2001	166th St.	IDEM	2000	
WWU070-0020	6/26/2001	166th St.	IDEM	580	
WWU070-0020	7/3/2001	166th St.	IDEM	1200	737
WWU070-0021	6/5/2001	Private Drive off SR 38	IDEM	2000	
WWU070-0021	6/12/2001	Private Drive off SR 38	IDEM	1600	

Stony Creek Watershed – *E. coli* data

STATION	DATE	DESCRIPTION	SOURCE	E.COLI MF	GEO. MEAN
WWU070-0021	6/19/2001	Private Drive off SR 38	IDEM	920	
WWU070-0021	6/26/2001	Private Drive off SR 38	IDEM	870	
WWU070-0021	7/3/2001	Private Drive off SR 38	IDEM	1100	1230
WWU070-0022	6/5/2001	SR 38	IDEM	1400	
WWU070-0022	6/5/2001	SR 38	IDEM	2000	
WWU070-0022	6/12/2001	SR 38	IDEM	770	
WWU070-0022	6/19/2001	SR 38	IDEM	1400	
WWU070-0022	6/26/2001	SR 38	IDEM	2000	1433
WWU070-0024	6/5/2001	E. 196th Street near Mystic Road	IDEM	1200	
WWU070-0024	6/12/2001	E. 196th Street near Mystic Road	IDEM	2000	
WWU070-0024	6/19/2001	E. 196th Street near Mystic Road	IDEM	1100	
WWU070-0024	6/26/2001	E. 196th Street near Mystic Road	IDEM	920	
WWU070-0024	7/3/2001	E. 196th Street near Mystic Road	IDEM	690	1109
WWU070-0025	6/5/2001	E. 196th St. near Mystic Road	IDEM	340	
WWU070-0025	6/12/2001	E. 196th St. near Mystic Road	IDEM	820	
WWU070-0025	6/12/2001	E. 196th St. near Mystic Road	IDEM	770	
WWU070-0025	6/19/2001	E. 196th St. near Mystic Road	IDEM	610	
WWU070-0025	6/26/2001	E. 196th St. near Mystic Road	IDEM	770	
WWU070-0025	7/3/2001	E. 196th St. near Mystic Road	IDEM	1300	713
WWU070-0026	6/5/2001	Not Listed	IDEM	1200	
WWU070-0026	6/12/2001	Not Listed	IDEM	2	
WWU070-0026	6/19/2001	Not Listed	IDEM	1400	
WWU070-0026	6/26/2001	Not Listed	IDEM	770	
WWU070-0026	7/3/2001	Not Listed	IDEM	870	
WWU070-0026	7/3/2001	Not Listed	IDEM	870	354
WWU070-0027	6/5/2001	Gravel Road off E. 196th Street	IDEM	730	
WWU070-0027	6/12/2001	Gravel Road off E. 196th Street	IDEM	870	
WWU070-0027	6/19/2001	Gravel Road off E. 196th Street	IDEM	2	
WWU070-0027	6/19/2001	Gravel Road off E. 196th Street	IDEM	2	
WWU070-0027	6/26/2001	Gravel Road off E. 196th Street	IDEM	870	
WWU070-0027	7/3/2001	Gravel Road off E. 196th Street	IDEM	2	41
WWU070-0028	6/5/2001	E. 206th Street near Durbin Rd.	IDEM	2400	
WWU070-0028	6/12/2001	E. 206th Street near Durbin Rd.	IDEM	730	
WWU070-0028	6/19/2001	E. 206th Street near Durbin Rd.	IDEM	2	
WWU070-0028	6/26/2001	E. 206th Street near Durbin Rd.	IDEM	2400	
WWU070-0028	7/3/2001	E. 206th Street near Durbin Rd.	IDEM	1000	
WWU070-0028	7/3/2001	E. 206th Street near Durbin Rd.	IDEM	980	449
WWU070-0029	6/5/2001	Cyntheanne Road	IDEM	1200	
WWU070-0029	6/12/2001	Cyntheanne Road	IDEM	820	
WWU070-0029	6/19/2001	Cyntheanne Road	IDEM	1300	

Stony Creek Watershed – *E. coli* data

STATION	DATE	DESCRIPTION	SOURCE	E.COLI MF	GEO. MEAN
WWU070-0029	6/26/2001	Cyntheanne Road	IDEM	1700	
WWU070-0029	7/3/2001	Cyntheanne Road	IDEM	410	977
WWU070-0030	6/5/2001	CR 1000 W.	IDEM	1000	
WWU070-0030	6/12/2001	CR 1000 W.	IDEM	1100	
WWU070-0030	6/19/2001	CR 1000 W.	IDEM	2	
WWU070-0030	6/26/2001	CR 1000 W.	IDEM	2400	
WWU070-0030	6/26/2001	CR 1000 W.	IDEM	2400	
WWU070-0030	7/3/2001	CR 1000 W.	IDEM	2	120
WWU070-0031	6/5/2001	SR 132/13	IDEM	610	
WWU070-0031	6/12/2001	SR 132/13	IDEM	2	
WWU070-0031	6/19/2001	SR 132/13	IDEM	920	
WWU070-0031	6/26/2001	SR 132/13	IDEM	2400	
WWU070-0031	7/3/2001	SR 132/13	IDEM	1300	323
WWU070-0032	6/5/2001	CR 925 West	IDEM	410	
WWU070-0032	6/12/2001	CR 925 West	IDEM	820	
WWU070-0032	6/19/2001	CR 925 West	IDEM	820	
WWU070-0032	6/26/2001	CR 925 West	IDEM	920	
WWU070-0032	7/3/2001	CR 925 West	IDEM	2400	905
WWU070-0033	6/5/2001	CR 825 W	IDEM	730	
WWU070-0033	6/12/2001	CR 825 W	IDEM	770	
WWU070-0033	6/19/2001	CR 825 W	IDEM	980	
WWU070-0033	6/26/2001	CR 825 W	IDEM	920	
WWU070-0033	7/3/2001	CR 825 W	IDEM	770	828
WWU070-0034	6/5/2001	CR 650 W	IDEM	580	
WWU070-0034	6/12/2001	CR 650 W	IDEM	490	
WWU070-0034	6/19/2001	CR 650 W	IDEM	520	
WWU070-0034	7/3/2001	CR 650 W	IDEM	250	491
1	5/13/2003	Atlantic Road	Stony Watershed WQ Assessment	65*	
1	6/27/2003	Atlantic Road	Stony Watershed WQ Assessment	1996*	
1	10/3/2003	Atlantic Road	Stony Watershed WQ Assessment	1109*	
2	5/13/2003	Wm. Lock Ditch	Stony Watershed WQ Assessment	146*	
2	6/27/2003	Wm. Lock Ditch	Stony Watershed WQ Assessment	168*	
2	10/3/2003	Wm. Lock Ditch	Stony Watershed WQ Assessment	157*	
3	5/13/2003	196th Street and Mystic Road	Stony Watershed WQ Assessment	230*	
3	6/27/2003	196th Street and Mystic Road	Stony Watershed WQ Assessment	283*	
3	10/3/2003	196th Street and Mystic Road	Stony Watershed WQ Assessment	110*	
4	5/13/2003	Highway 38	Stony Watershed WQ Assessment	212*	
4	6/27/2003	Highway 38	Stony Watershed WQ Assessment	662*	
4	10/3/2003	Highway 38	Stony Watershed WQ Assessment	180*	
5	5/13/2003	166 Street near Boden Road	Stony Watershed WQ Assessment	156*	

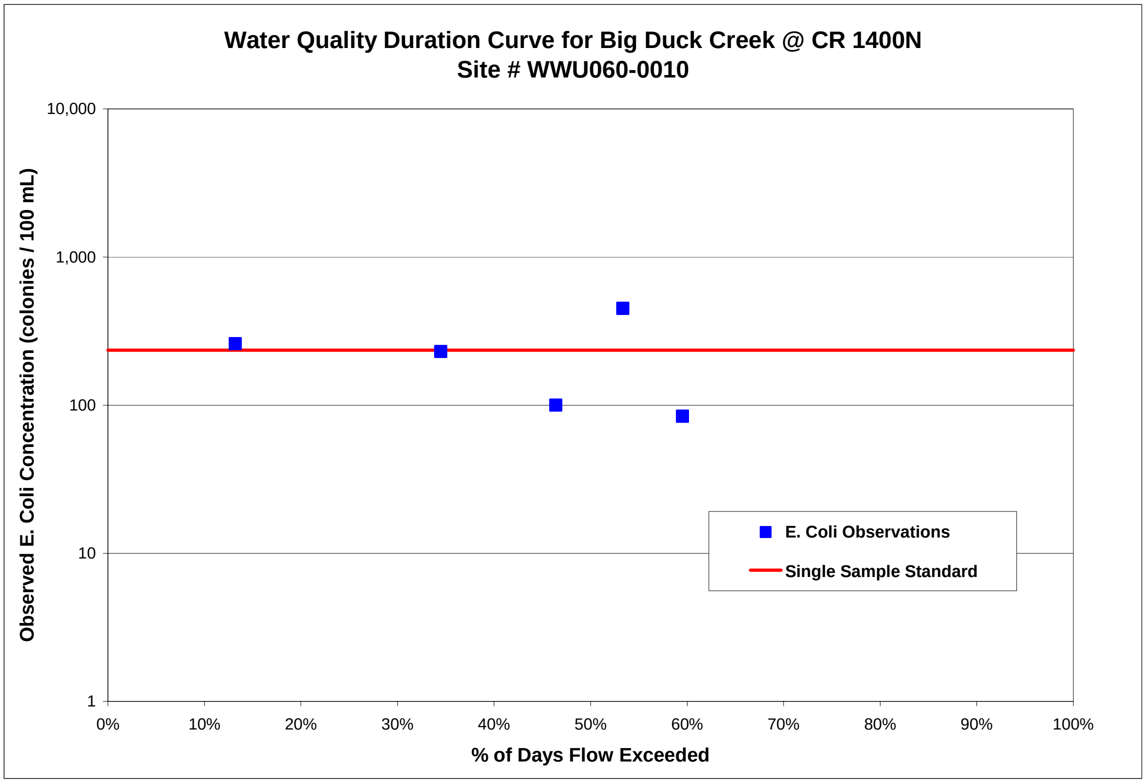
Stony Creek Watershed – *E. coli* data

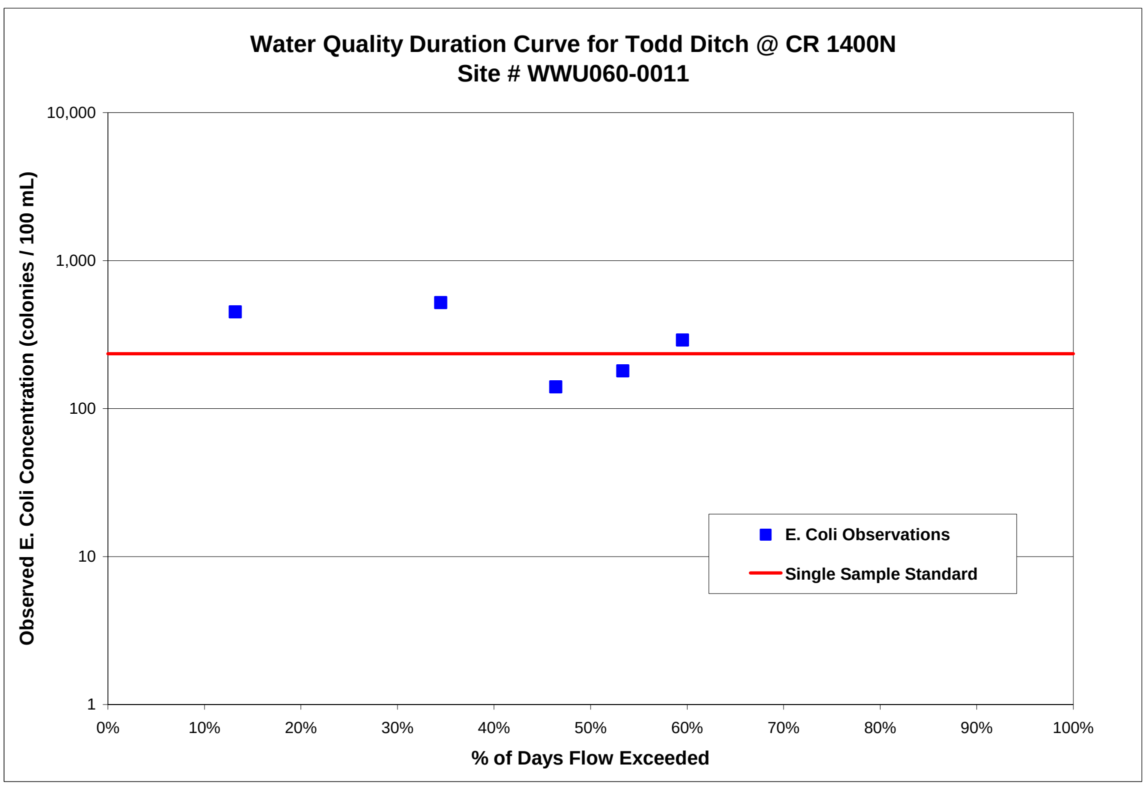
STATION	DATE	DESCRIPTION	SOURCE	E.COLI MF	GEO. MEAN
5	6/27/2003	166 Street near Boden Road	Stony Watershed WQ Assessment	1996*	
5	10/3/2003	166 Street near Boden Road	Stony Watershed WQ Assessment	132*	
6	5/13/2003	Cumberland Road	Stony Watershed WQ Assessment	247*	
6	6/27/2003	Cumberland Road	Stony Watershed WQ Assessment	290*	
6	10/3/2003	Cumberland Road	Stony Watershed WQ Assessment	327*	
7	5/13/2003	Greenfield Road	Stony Watershed WQ Assessment	262*	
7	6/27/2003	Greenfield Road	Stony Watershed WQ Assessment	174*	
7	10/3/2003	Greenfield Road	Stony Watershed WQ Assessment	236*	
8	5/13/2003	Allisonville Road	Stony Watershed WQ Assessment	1364*	
8	6/27/2003	Allisonville Road	Stony Watershed WQ Assessment	236*	
8	10/3/2003	Allisonville Road	Stony Watershed WQ Assessment	200*	
2A	5/13/2003	Pilgrim Road	Stony Watershed WQ Assessment	262*	
2A	6/27/2003	Pilgrim Road	Stony Watershed WQ Assessment	2746*	
2A	10/3/2003	Pilgrim Road	Stony Watershed WQ Assessment	158*	

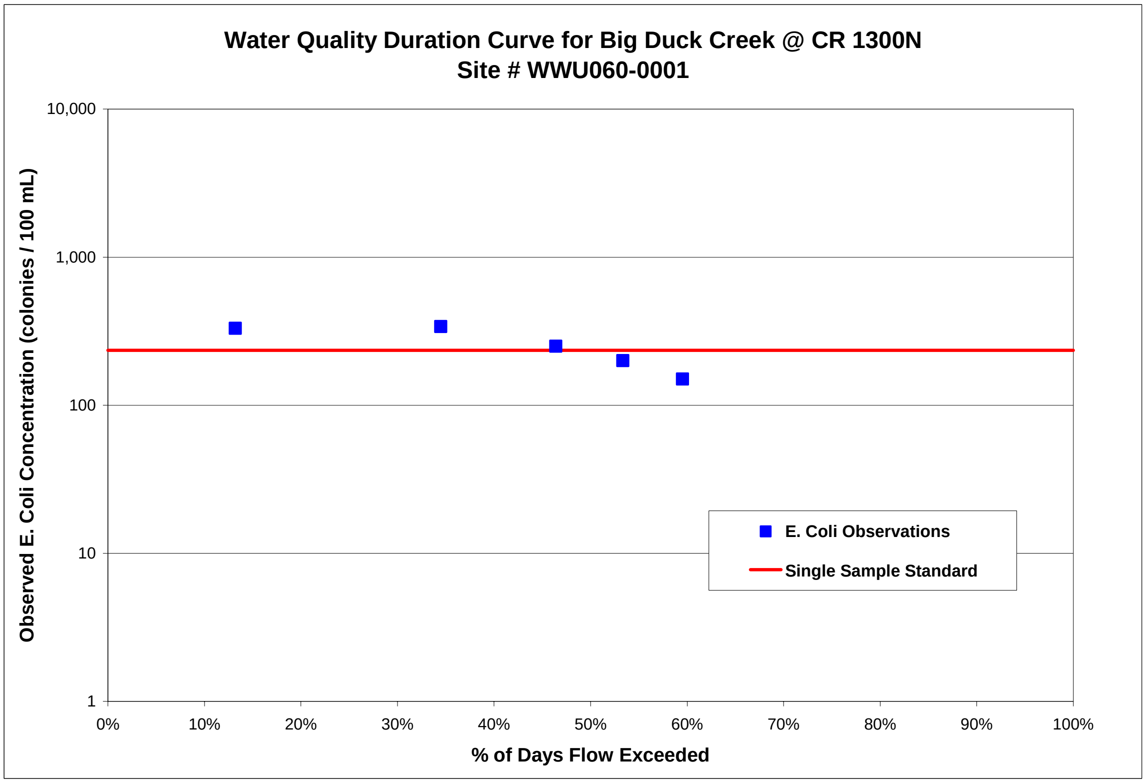
APPENDIX B

WATER QUALITY DURATION CURVES

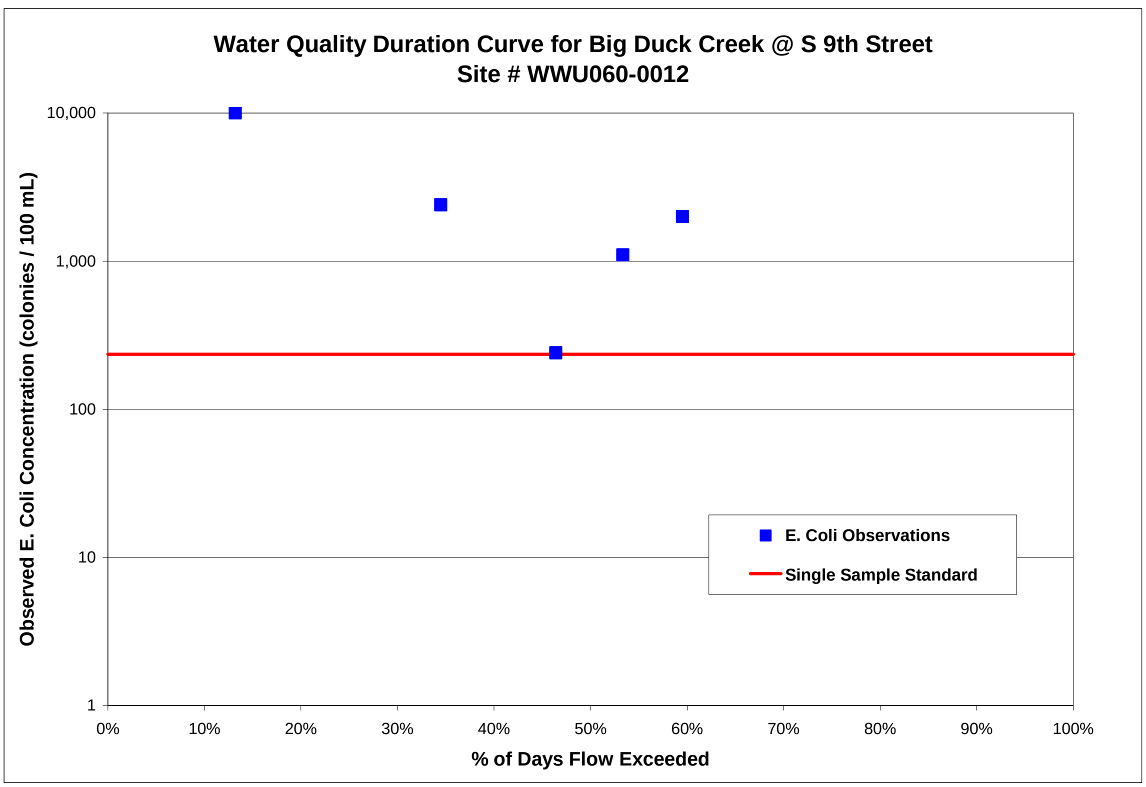
Water Quality Duration Curves for Duck Creek Watershed



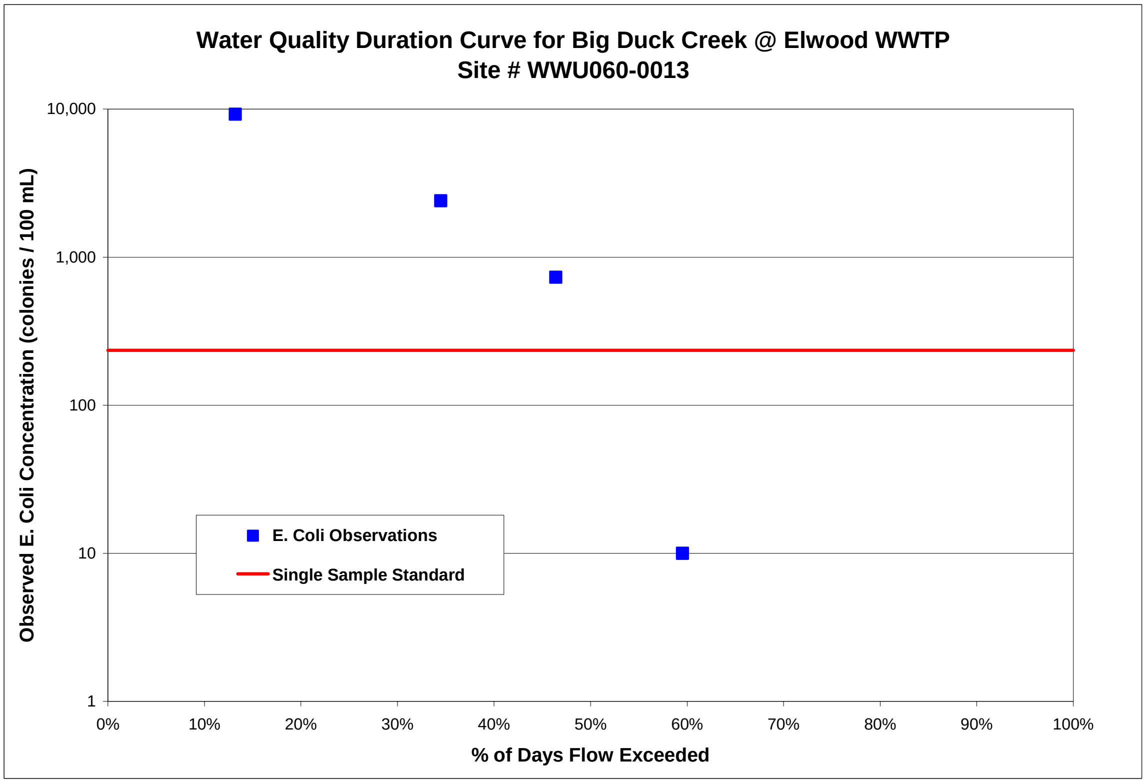


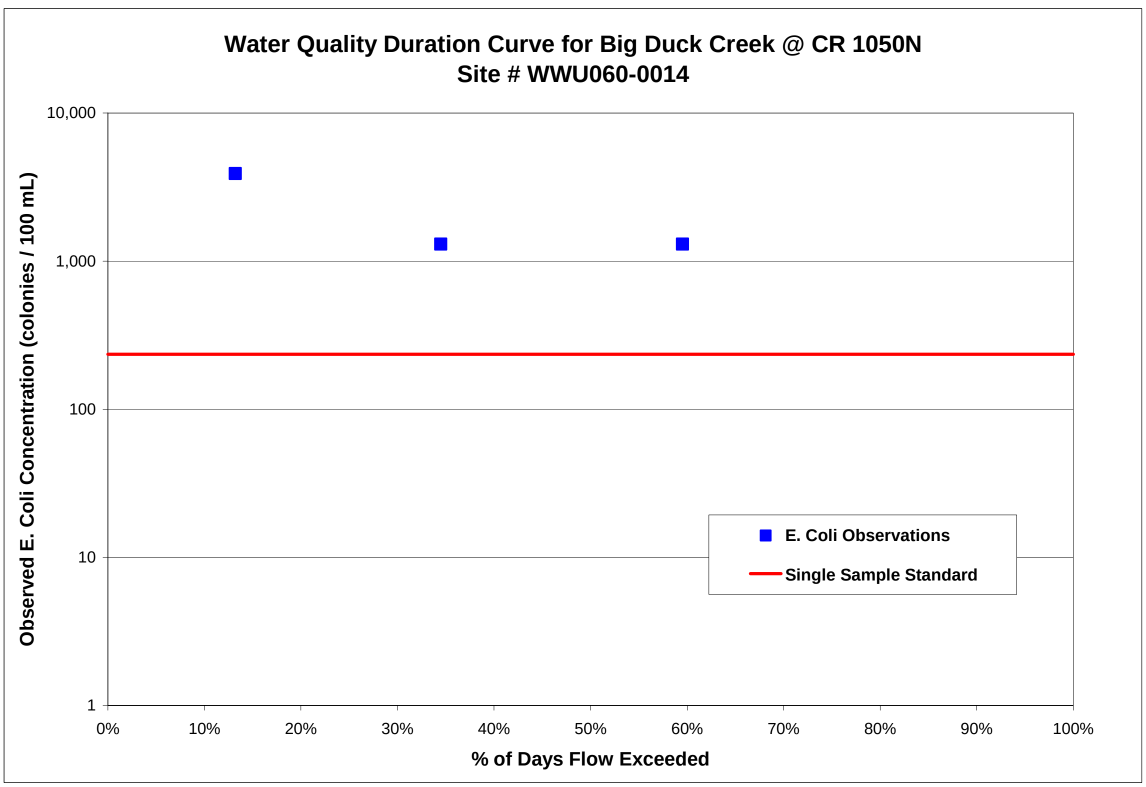


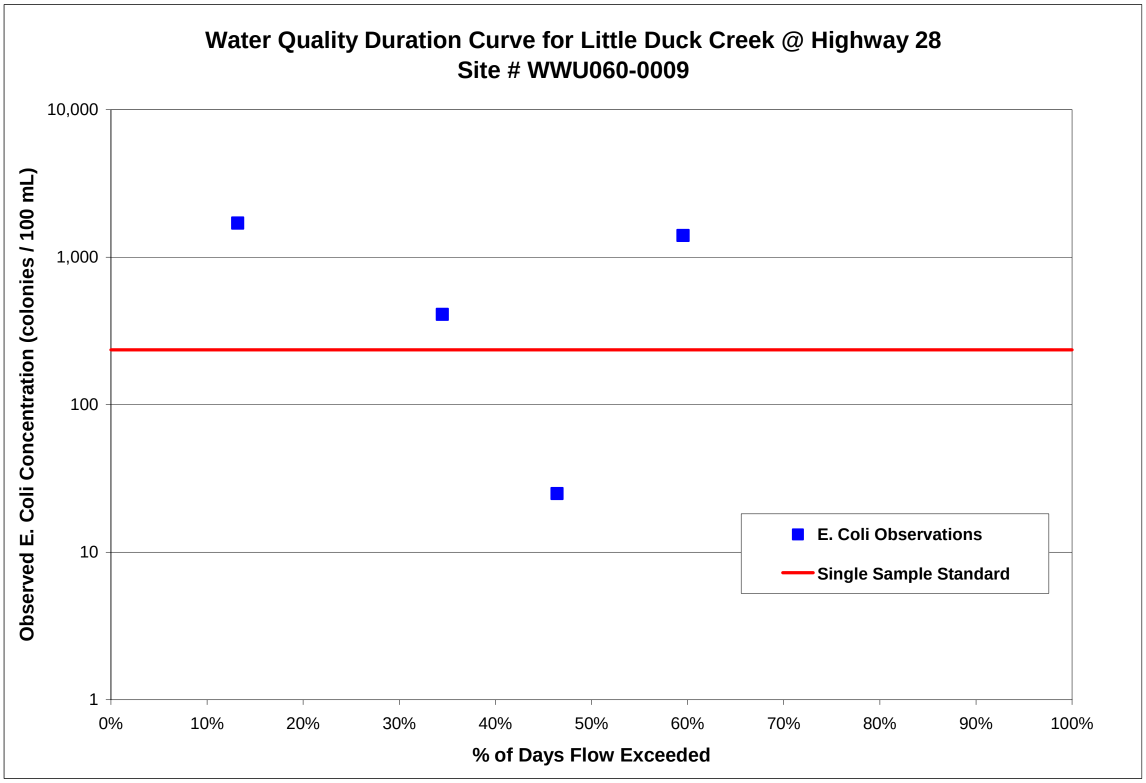
Water Quality Duration Curve for Big Duck Creek @ CR 1300N
Site # WWU060-0001
Observed E. Coli Concentration (colonies / 100 mL)
10,000
1,000
100
10
1
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
% of Days Flow Exceeded
E. Coli Observations
Single Sample Standard

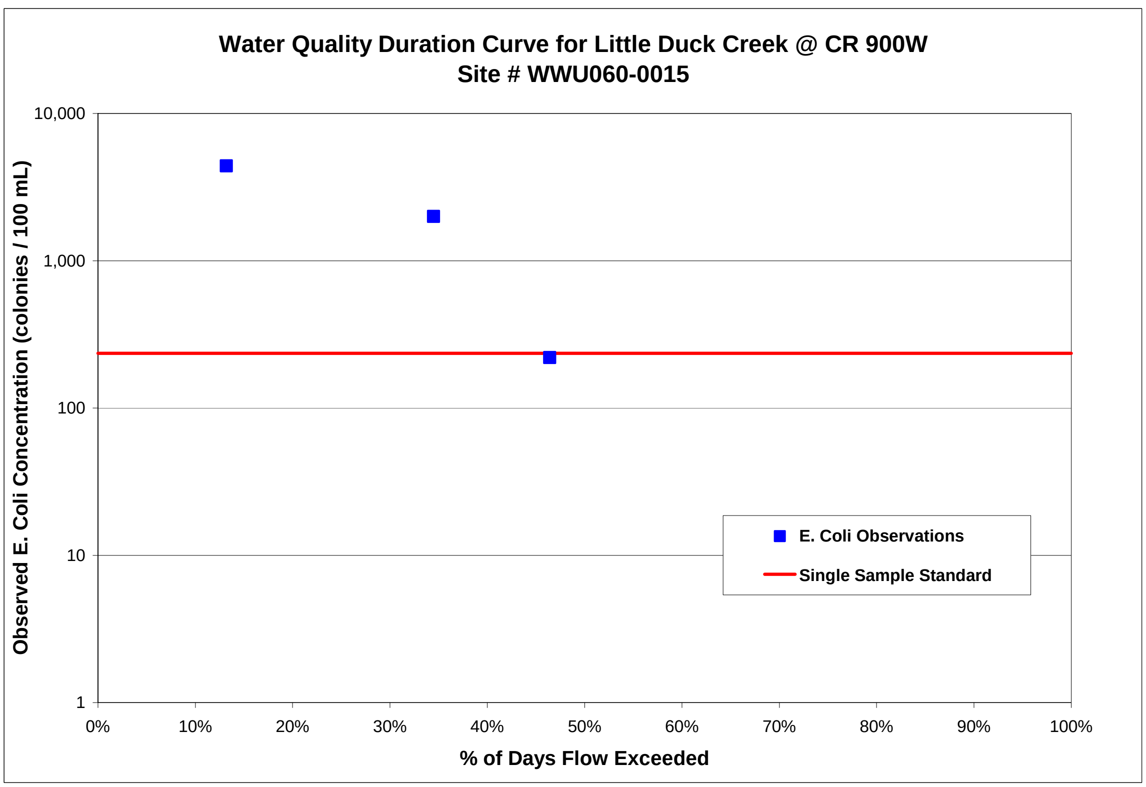


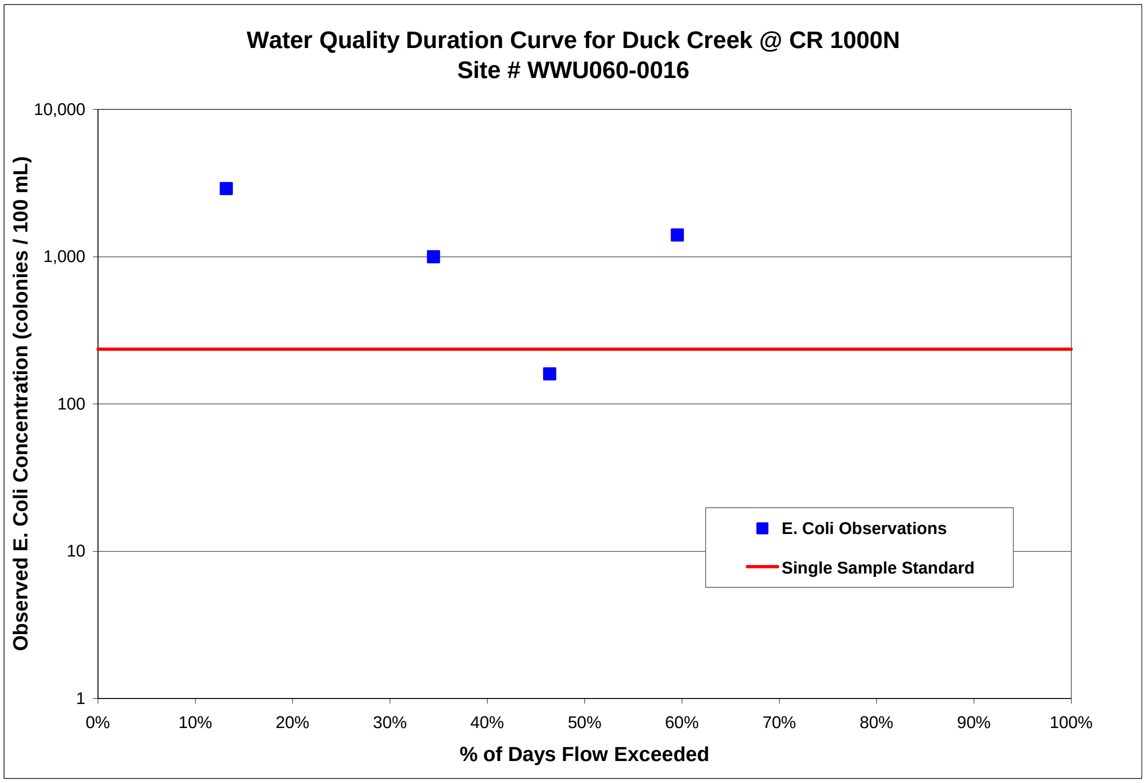
Water Quality Duration Curve for Big Duck Creek @ S 9th Street
Site # WWU060-0012
Observed E. Coli Concentration (colonies / 100 mL)
10,000
1,000
100
10
1
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
% of Days Flow Exceeded
E. Coli Observations
Single Sample Standard


Water Quality Duration Curve for Big Duck Creek @ Elwood WWTP
Site # WWU060-0013
10,000
1,000
100
10
1
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
Observed E. Coli Concentration (colonies / 100 mL)
% of Days Flow Exceeded
E. Coli Observations
Single Sample Standard

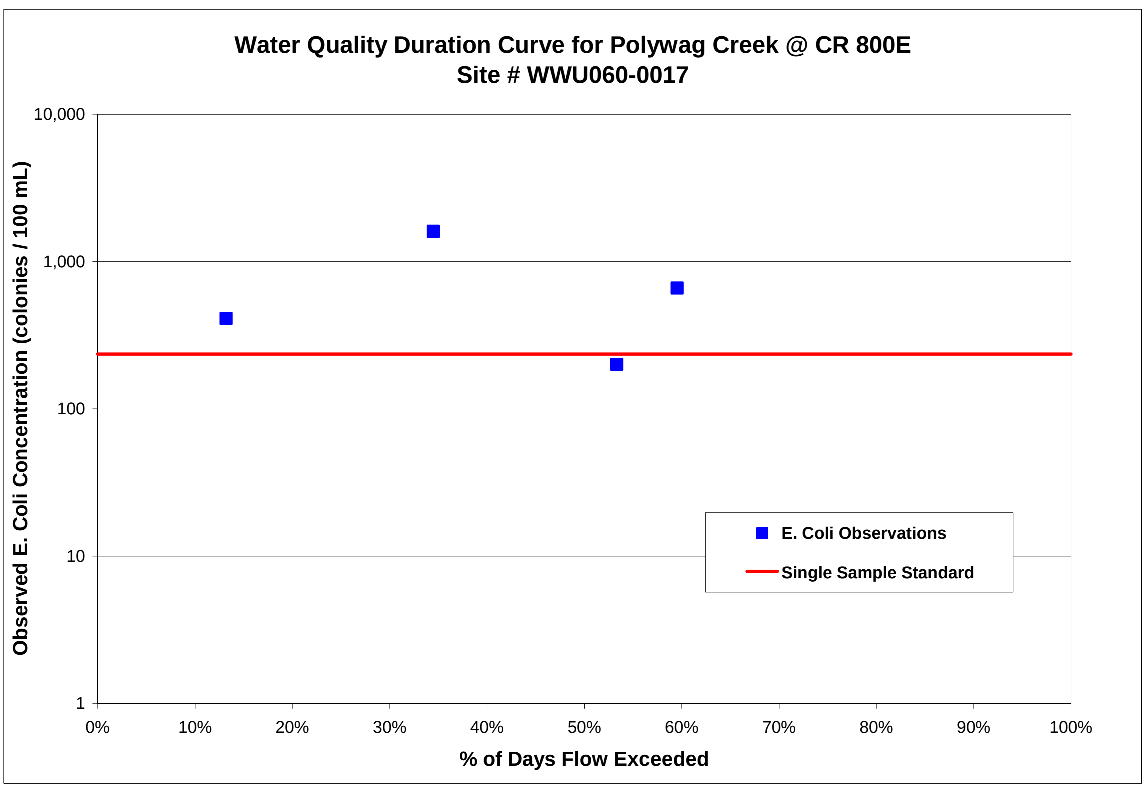

Water Quality Duration Curve for Big Duck Creek @ CR 1050N
Site # WWU060-0014
10,000
1,000
100
10
1
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
Observed E. Coli Concentration (colonies / 100 mL)
% of Days Flow Exceeded
E. Coli Observations
Single Sample Standard


Water Quality Duration Curve for Little Duck Creek @ Highway 28
Site # WWU060-0009
10,000
1,000
100
10
1
Observed E. Coli Concentration (colonies / 100 mL)
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
% of Days Flow Exceeded
E. Coli Observations
Single Sample Standard

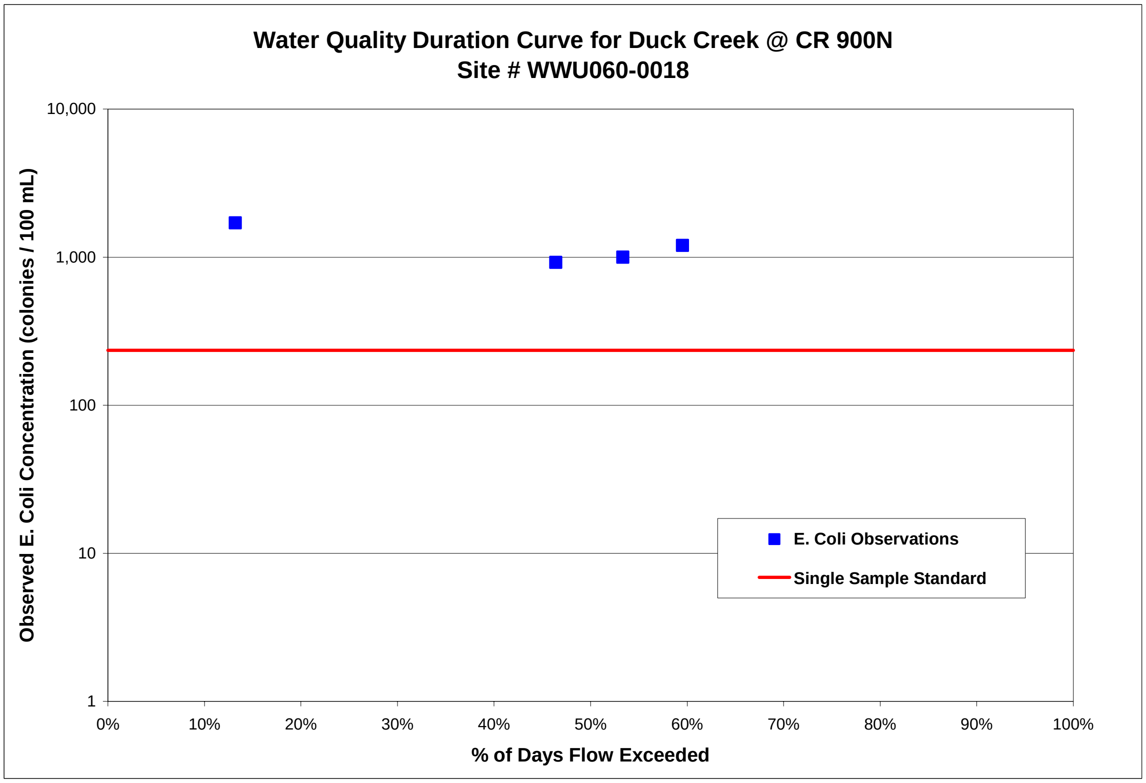

Water Quality Duration Curve for Little Duck Creek @ CR 900W
Site # WWU060-0015
10,000
1,000
100
10
1
Observed E. Coli Concentration (colonies / 100 mL)
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
% of Days Flow Exceeded
E. Coli Observations
Single Sample Standard

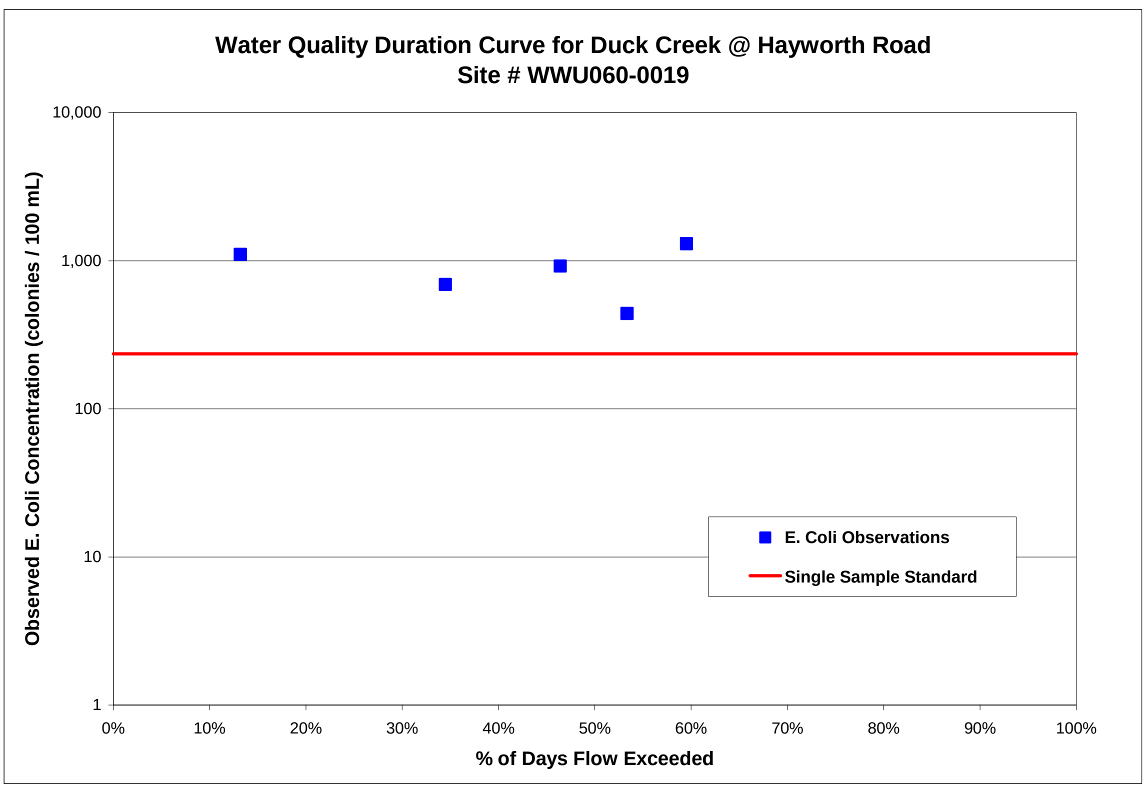


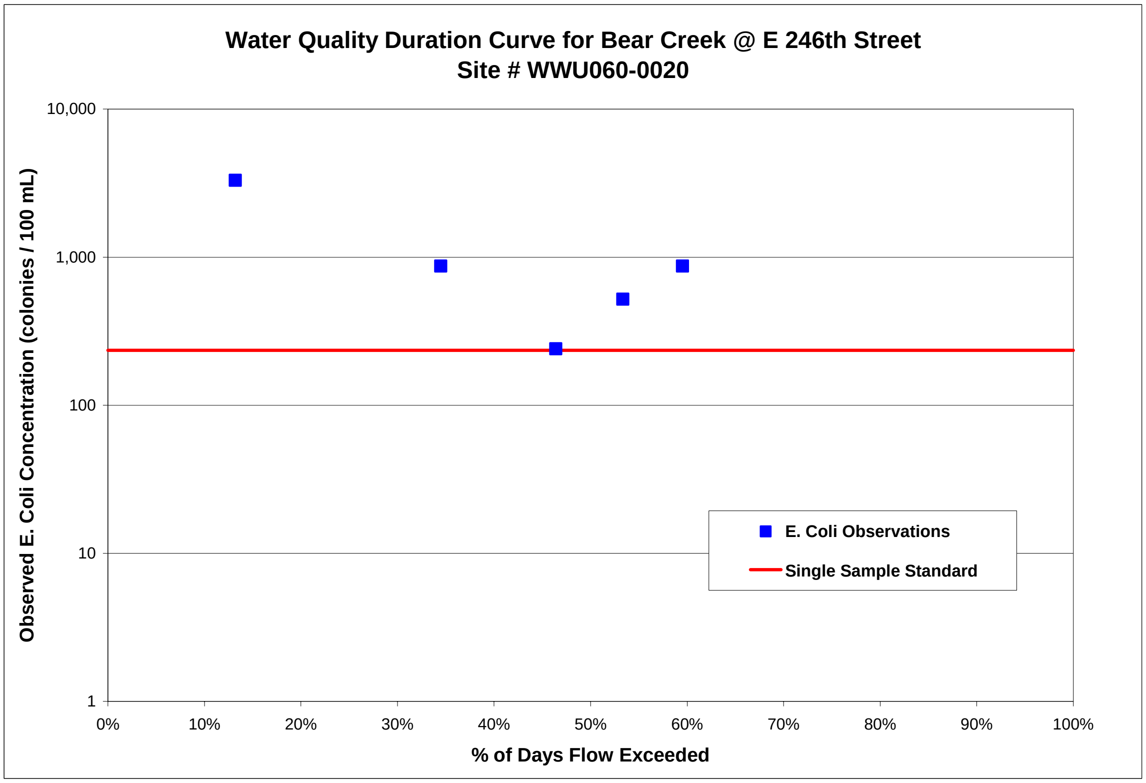
Water Quality Duration Curve for Duck Creek @ CR 1000N
Site # WWU060-0016
10,000
1,000
100
10
1
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
Observed E. Coli Concentration (colonies / 100 mL)
% of Days Flow Exceeded
E. Coli Observations
Single Sample Standard

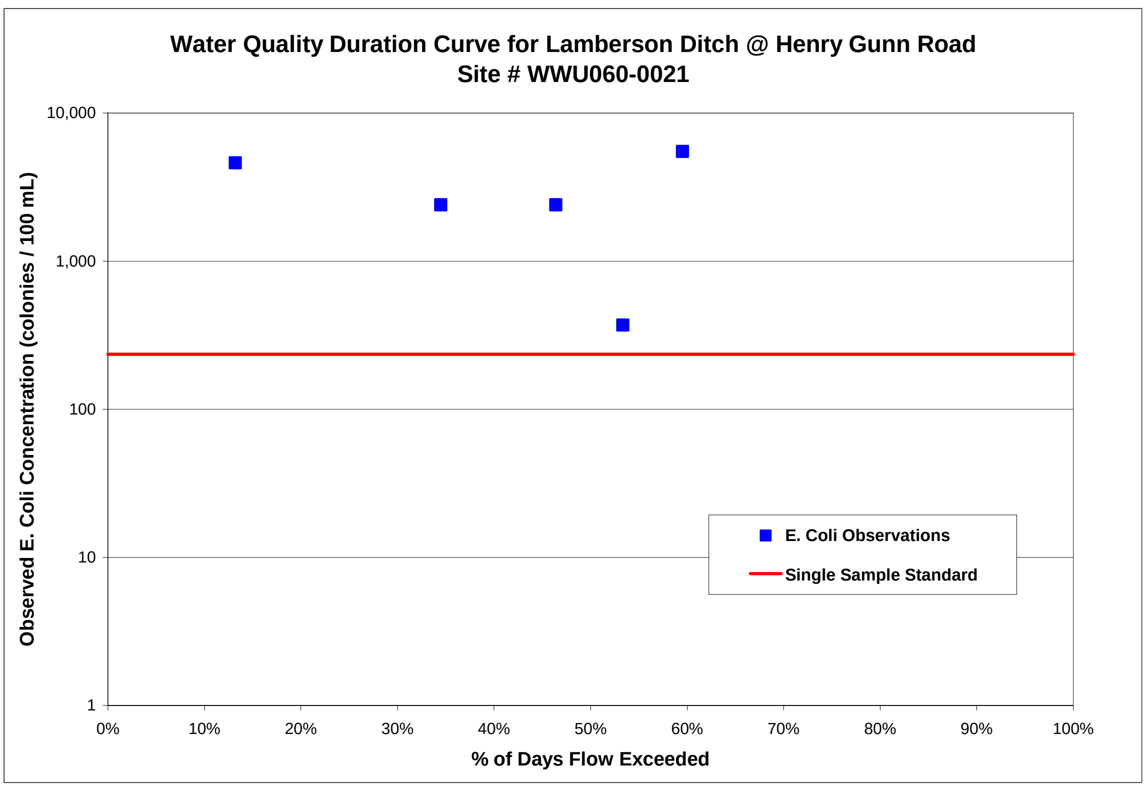


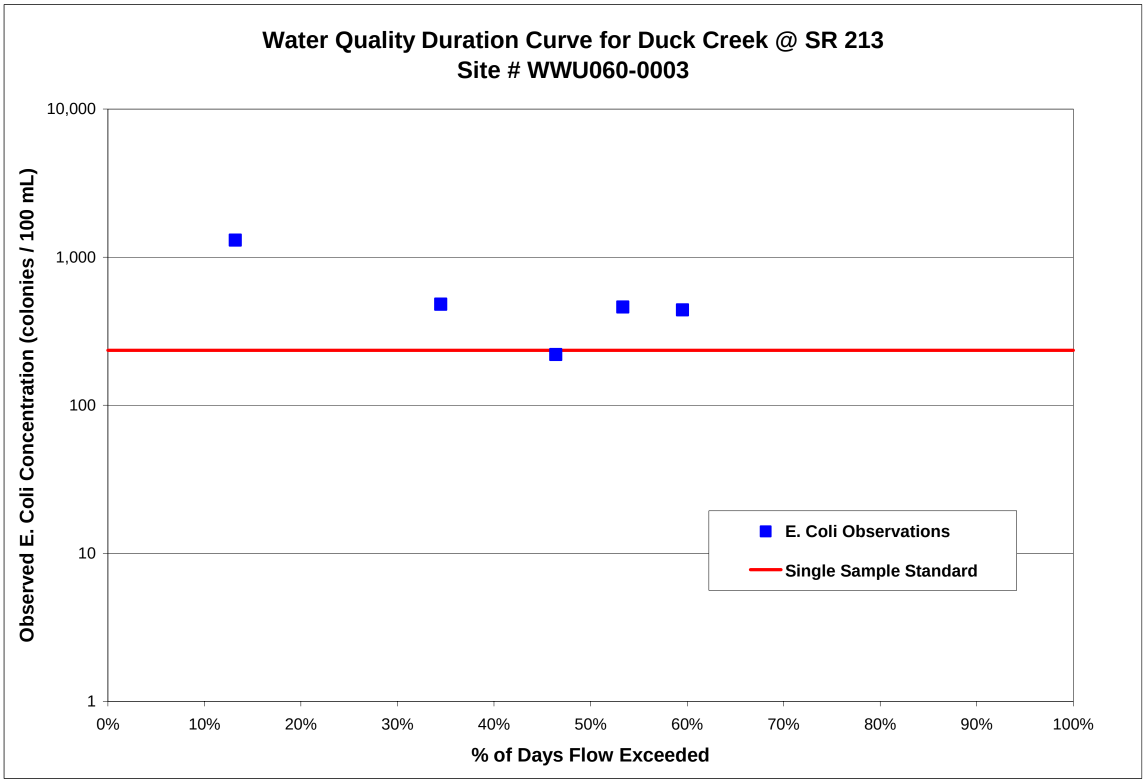
Water Quality Duration Curve for Polywag Creek @ CR 800E
Site # WWU060-0017
10,000
1,000
100
10
1
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
Observed E. Coli Concentration (colonies / 100 mL)
% of Days Flow Exceeded
E. Coli Observations
Single Sample Standard


Water Quality Duration Curve for Duck Creek @ CR 900N
Site # WWU060-0018
10,000
1,000
100
10
1
Observed E. Coli Concentration (colonies / 100 mL)
E. Coli Observations
Single Sample Standard
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
% of Days Flow Exceeded


Water Quality Duration Curve for Duck Creek @ Hayworth Road
Site # WWU060-0019
10,000
1,000
100
10
1
Observed E. Coli Concentration (colonies / 100 mL)
E. Coli Observations
Single Sample Standard
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
% of Days Flow Exceeded

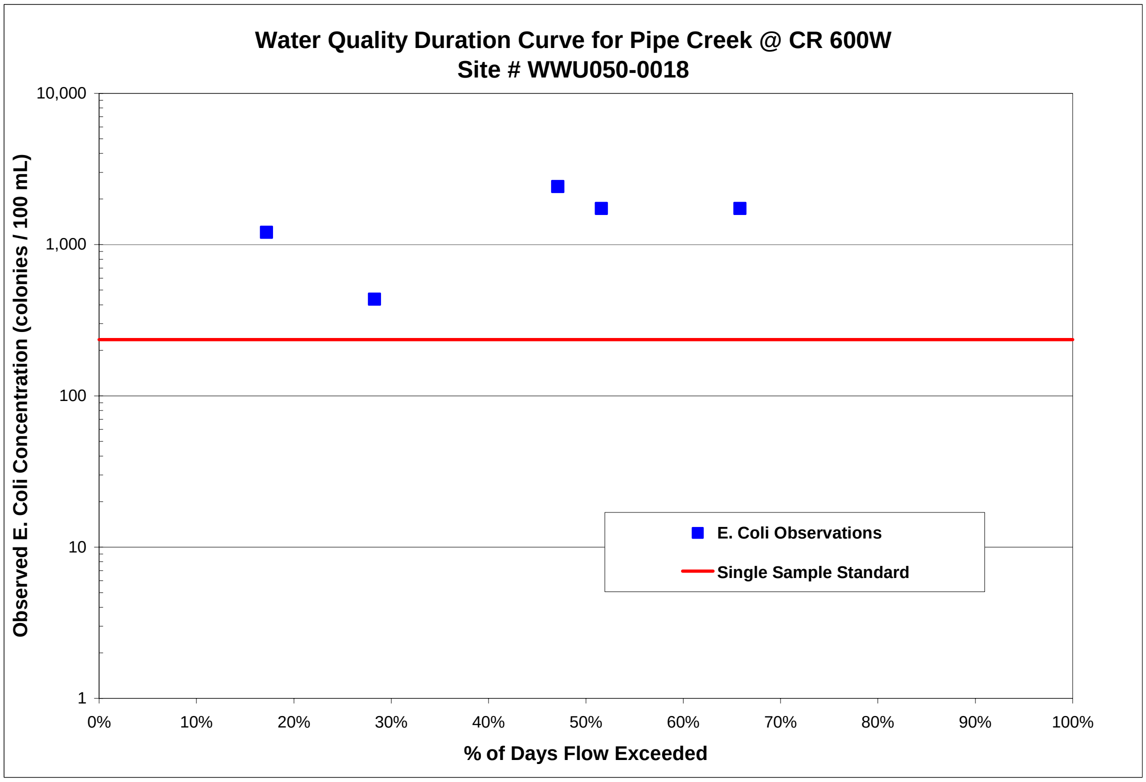

Water Quality Duration Curve for Bear Creek @ E 246th Street
Site # WWU060-0020
10,000
1,000
100
10
1
Observed E. Coli Concentration (colonies / 100 mL)
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
% of Days Flow Exceeded
E. Coli Observations
Single Sample Standard

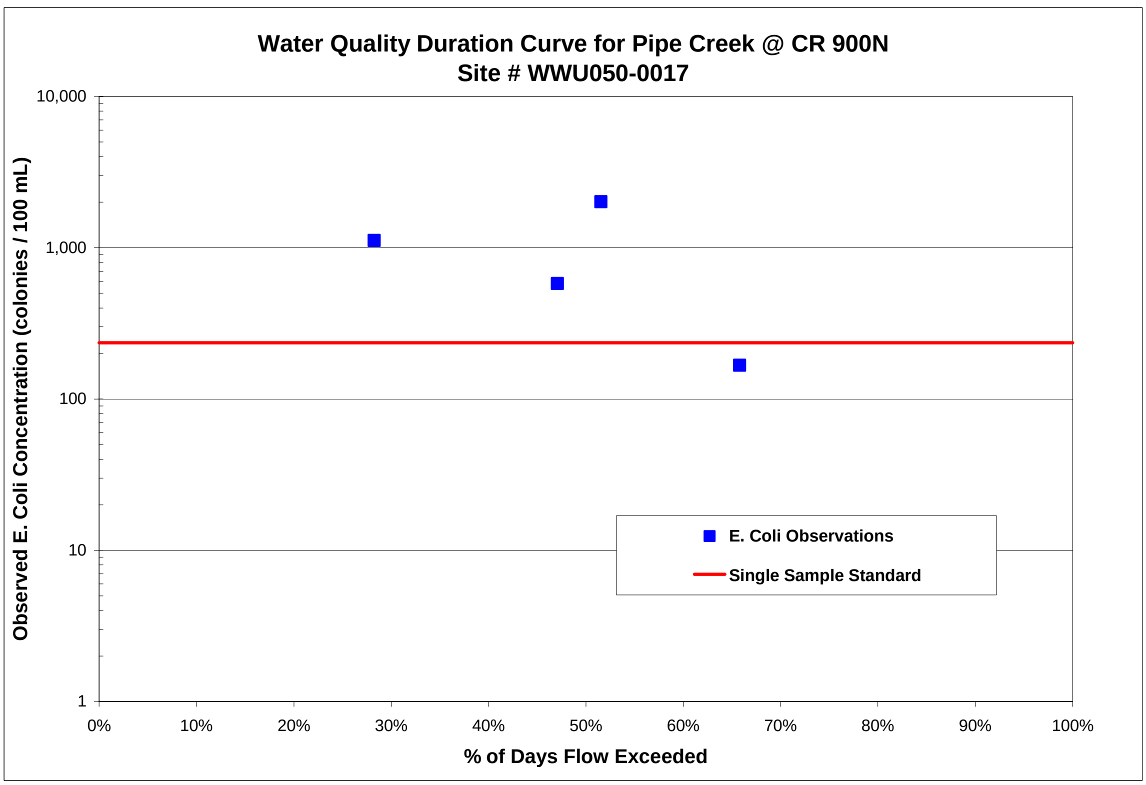

Water Quality Duration Curve for Lamberson Ditch @ Henry Gunn Road
Site # WWU060-0021
10,000
1,000
100
10
1
Observed E. Coli Concentration (colonies / 100 mL)
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
% of Days Flow Exceeded
E. Coli Observations
Single Sample Standard

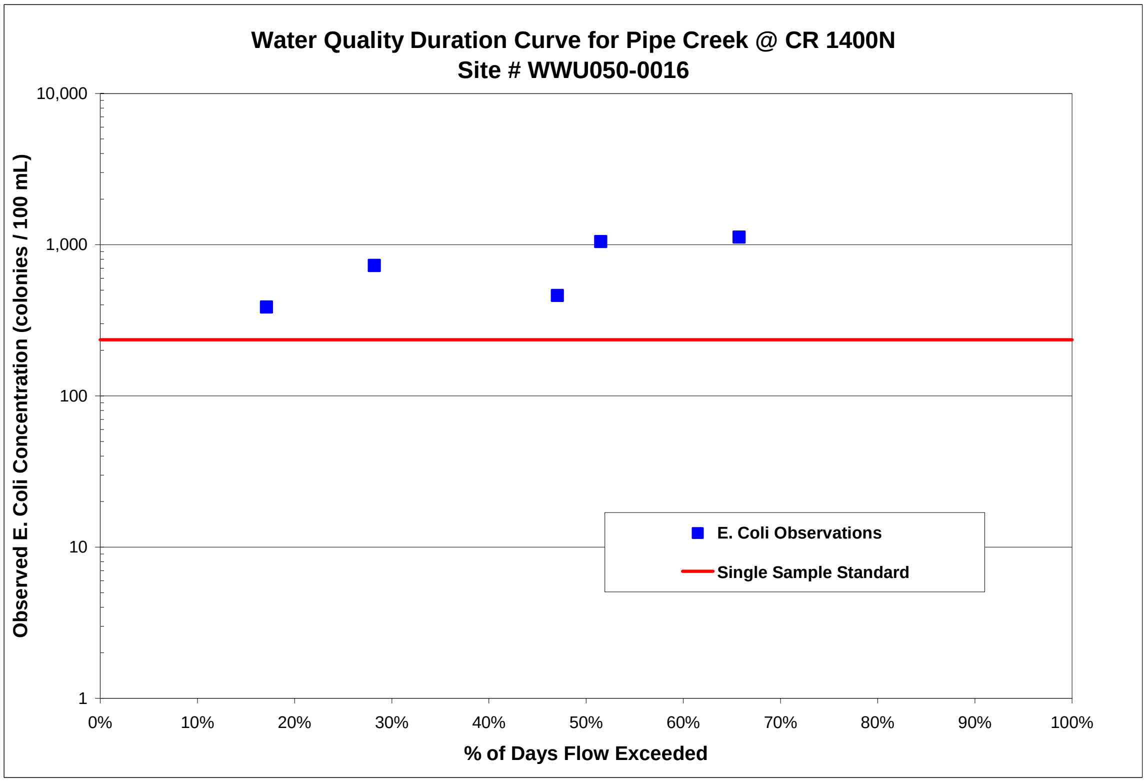


Water Quality Duration Curve for Duck Creek @ SR 213
Site # WWU060-0003
Observed E. Coli Concentration (colonies / 100 mL)
10,000
1,000
100
10
1
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
% of Days Flow Exceeded
E. Coli Observations
Single Sample Standard

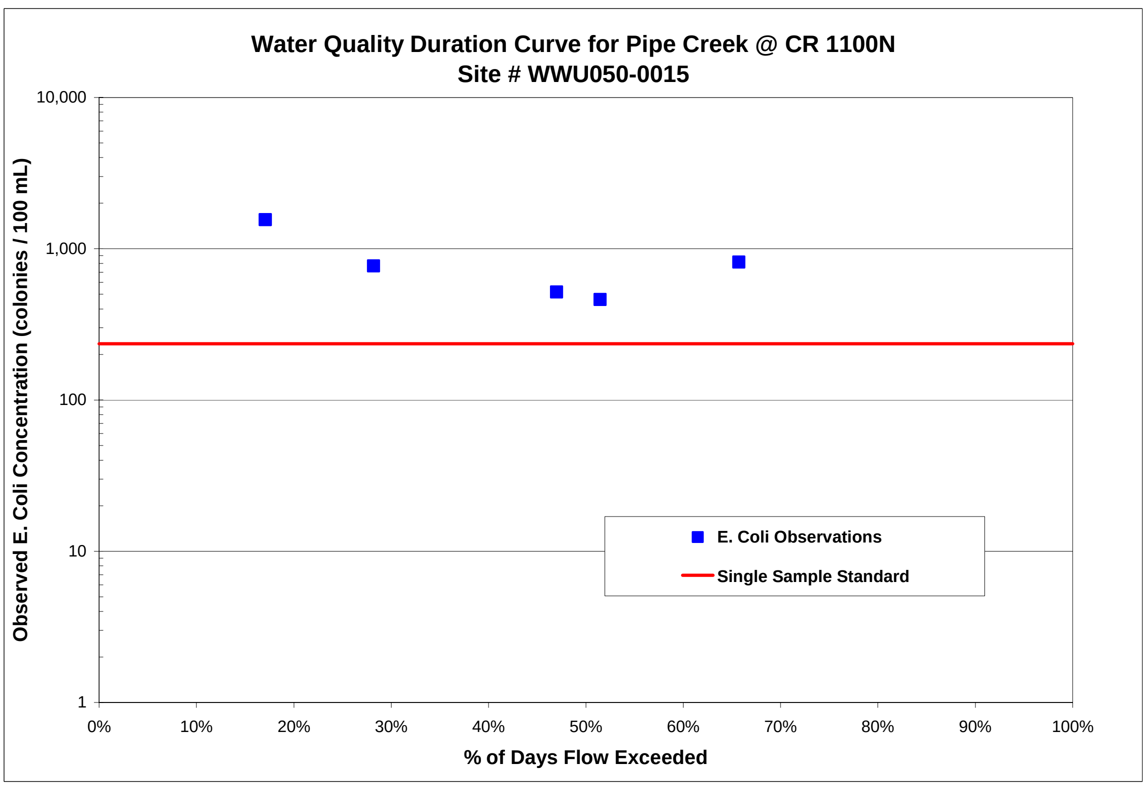
Water Quality Duration Curves for Pipe Creek Watershed



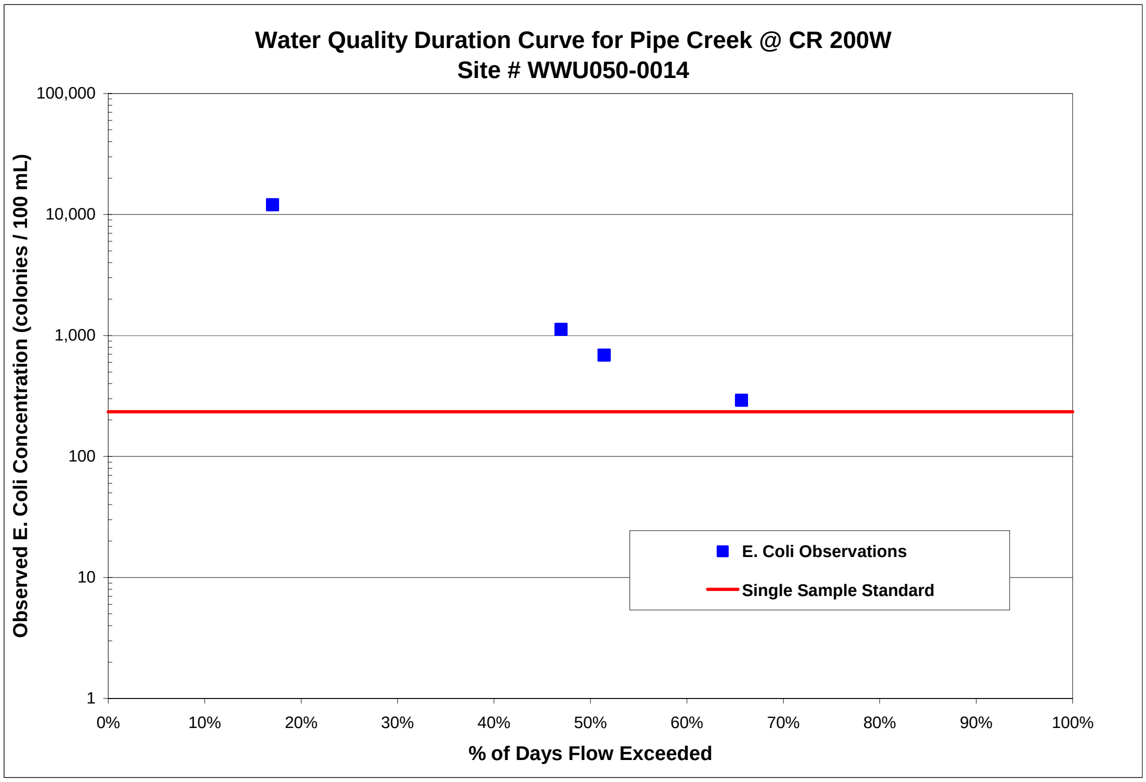




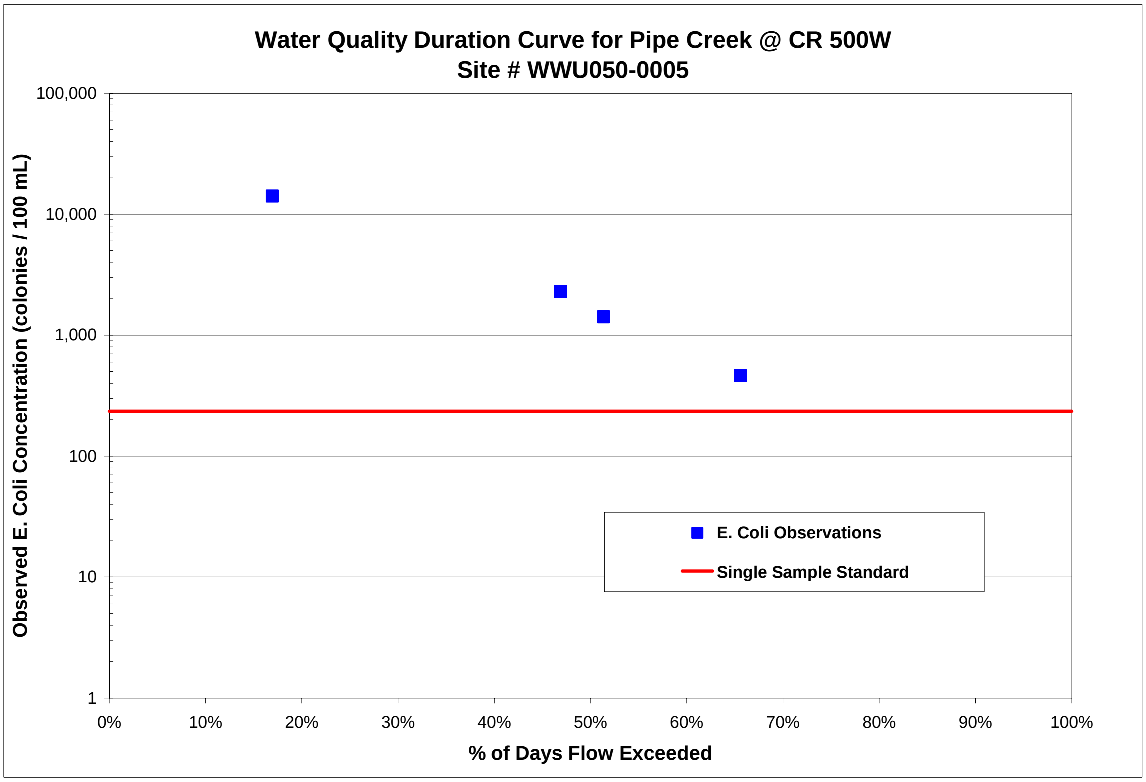
Water Quality Duration Curve for Pipe Creek @ CR 1400N
Site # WWU050-0016
10,000
1,000
100
10
1
Observed E. Coli Concentration (colonies / 100 mL)
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
% of Days Flow Exceeded
E. Coli Observations
Single Sample Standard



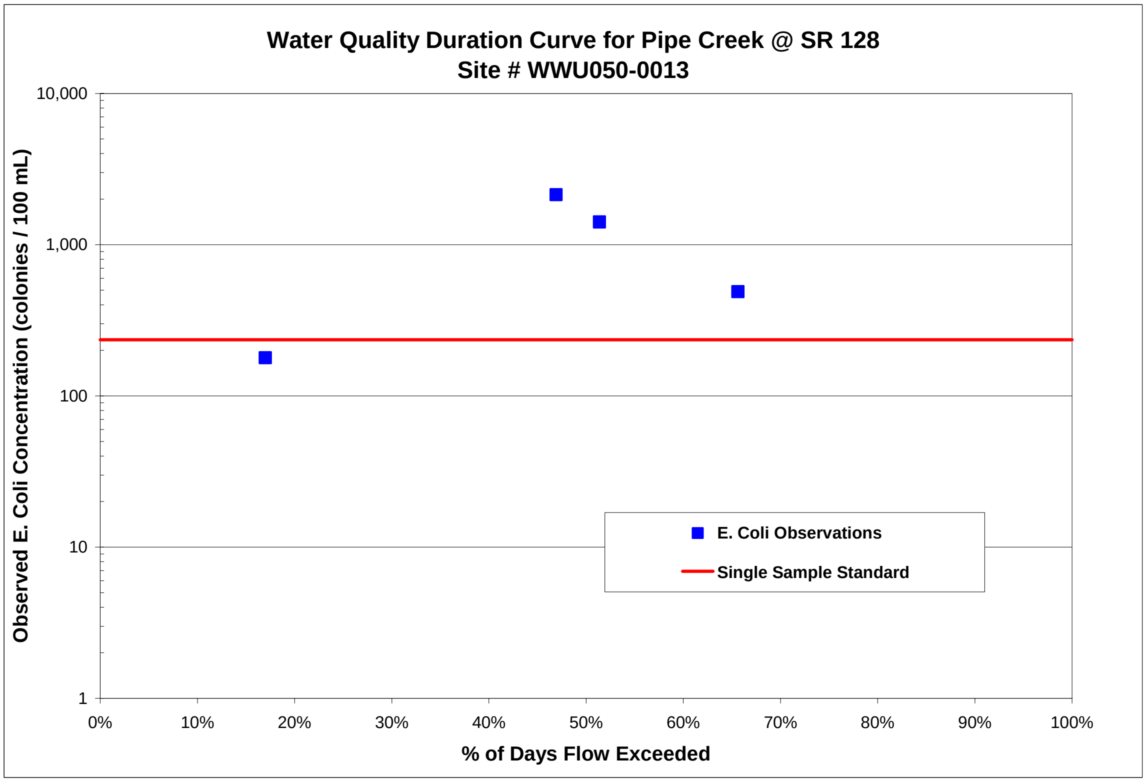
Water Quality Duration Curve for Pipe Creek @ CR 1100N
Site # WWU050-0015
10,000
1,000
100
10
1
Observed E. Coli Concentration (colonies / 100 mL)
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
% of Days Flow Exceeded
E. Coli Observations
Single Sample Standard

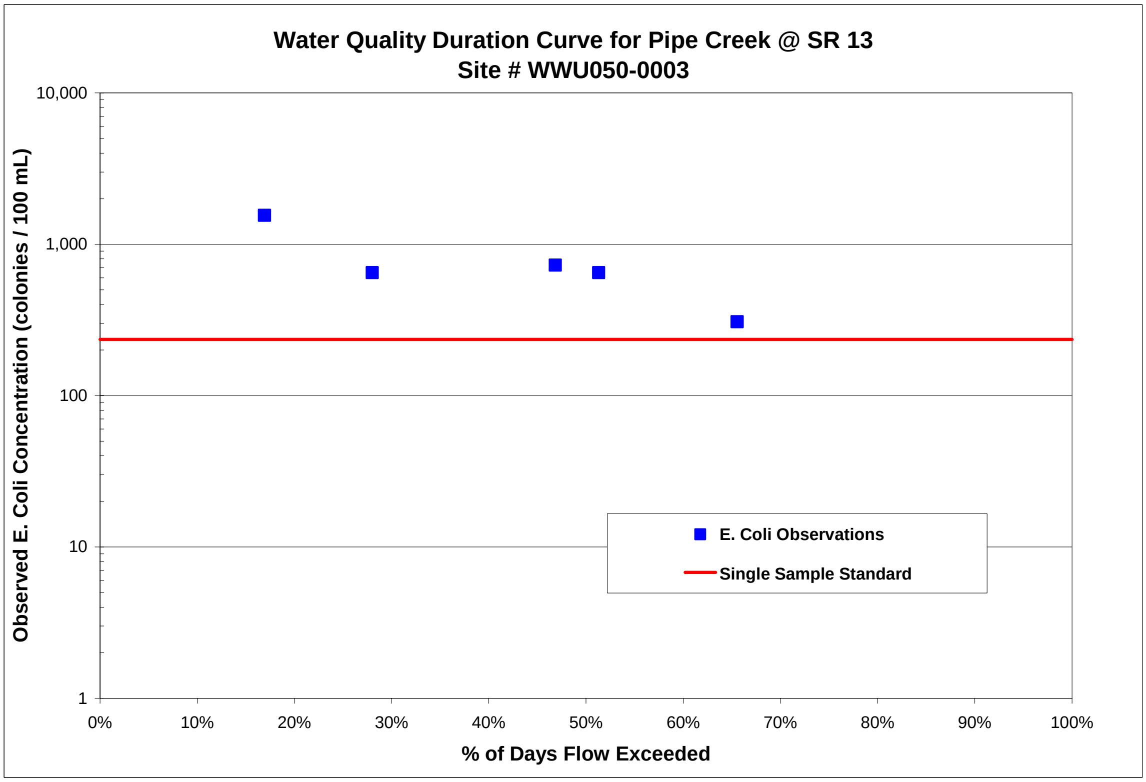


Water Quality Duration Curve for Pipe Creek @ CR 200W
Site # WWU050-0014
Observed E. Coli Concentration (colonies / 100 mL)
100,000
10,000
1,000
100
10
1
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
% of Days Flow Exceeded
E. Coli Observations
Single Sample Standard

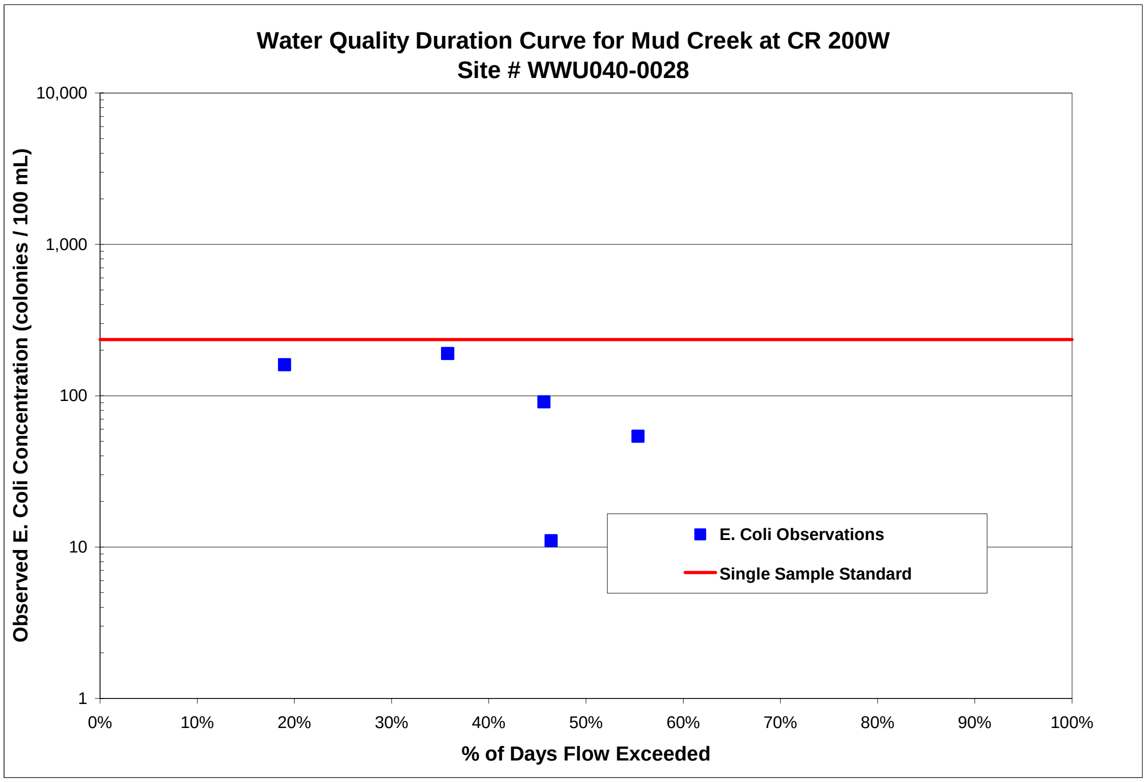


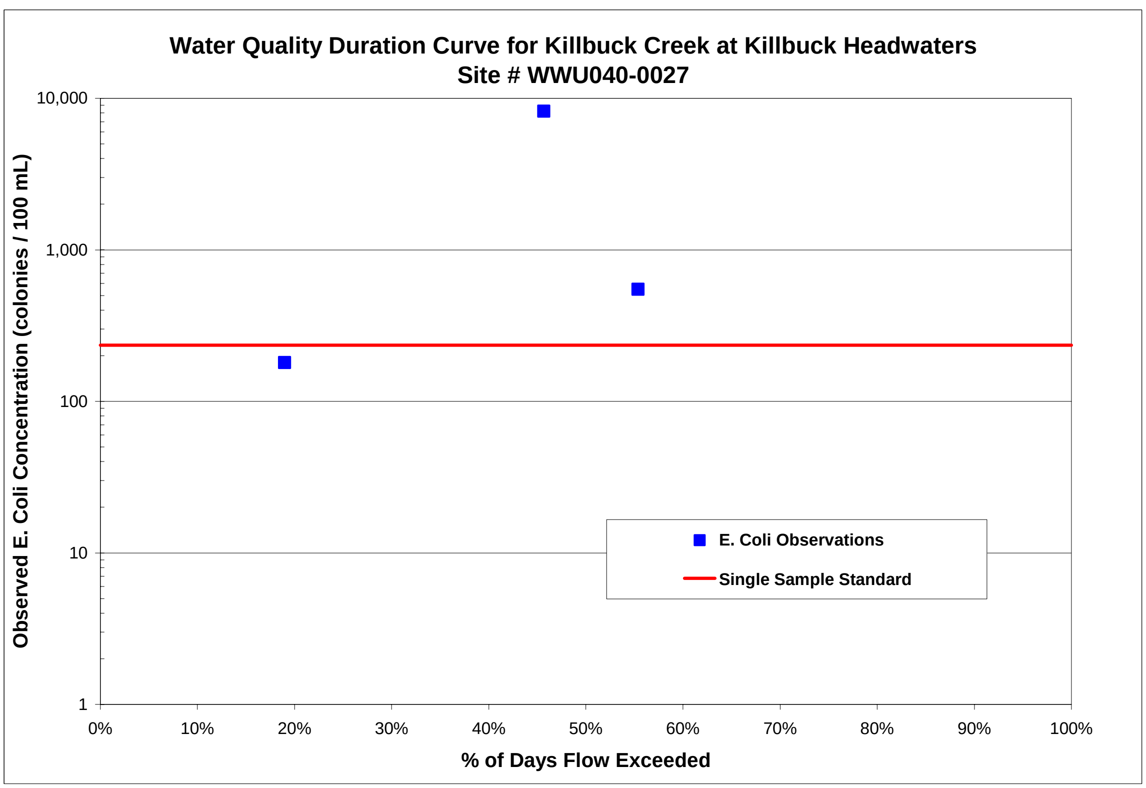
Water Quality Duration Curve for Pipe Creek @ CR 500W
Site # WWU050-0005
Observed E. Coli Concentration (colonies / 100 mL)
100,000
10,000
1,000
100
10
1
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
% of Days Flow Exceeded
E. Coli Observations
Single Sample Standard

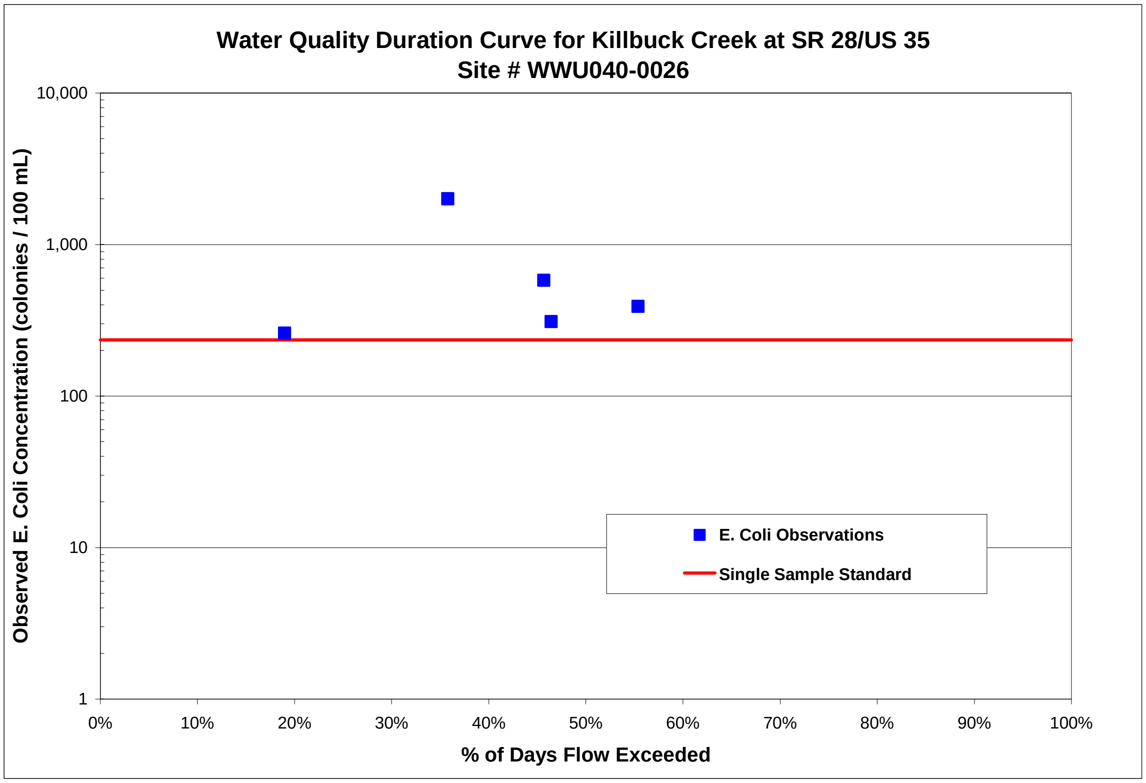

Water Quality Duration Curve for Pipe Creek @ SR 128
Site # WWU050-0013
Observed E. Coli Concentration (colonies / 100 mL)
10,000
1,000
100
10
1
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
% of Days Flow Exceeded
E. Coli Observations
Single Sample Standard


Water Quality Duration Curve for Pipe Creek @ SR 13
Site # WWU050-0003
Observed E. Coli Concentration (colonies / 100 mL)
10,000
1,000
100
10
1
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
% of Days Flow Exceeded
E. Coli Observations
Single Sample Standard

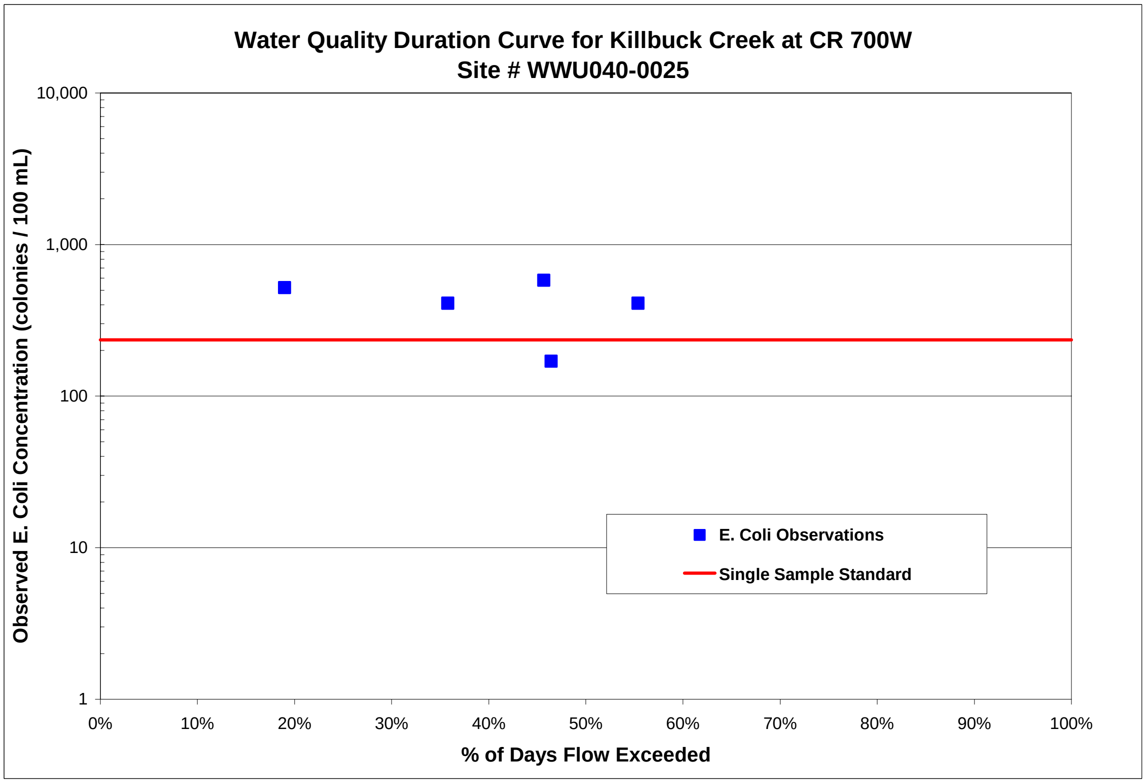
Water Quality Duration Curves for Killbuck Creek Watershed



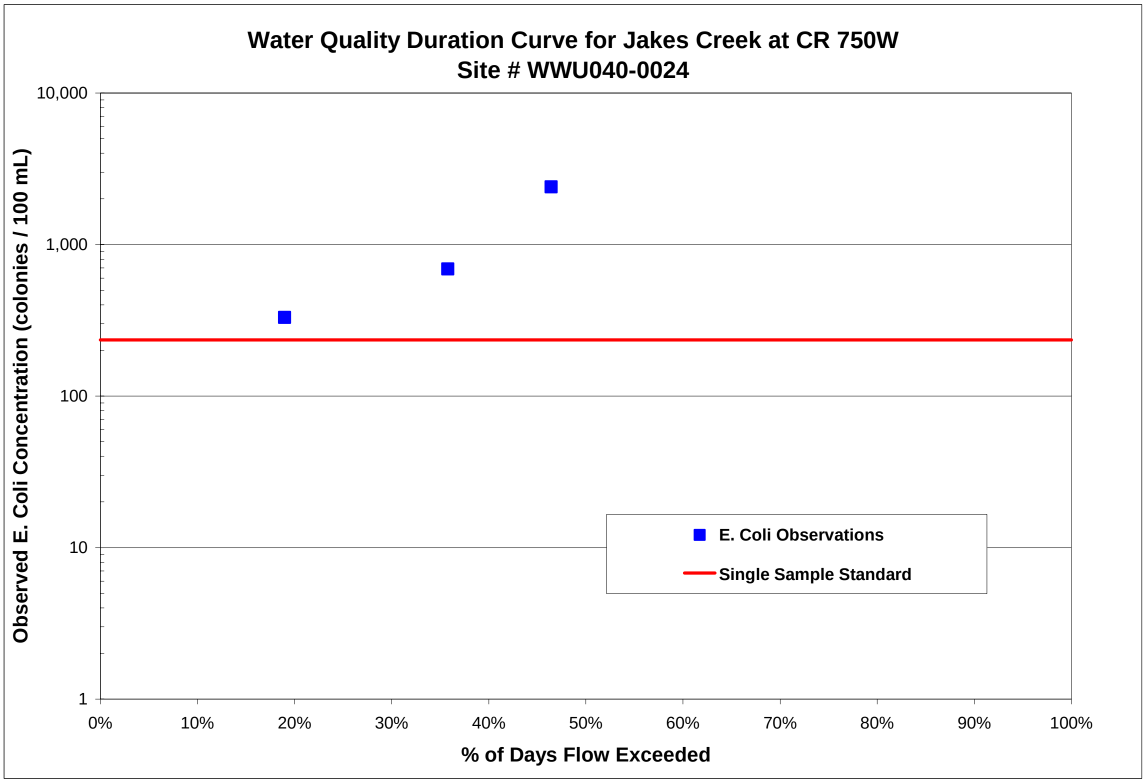


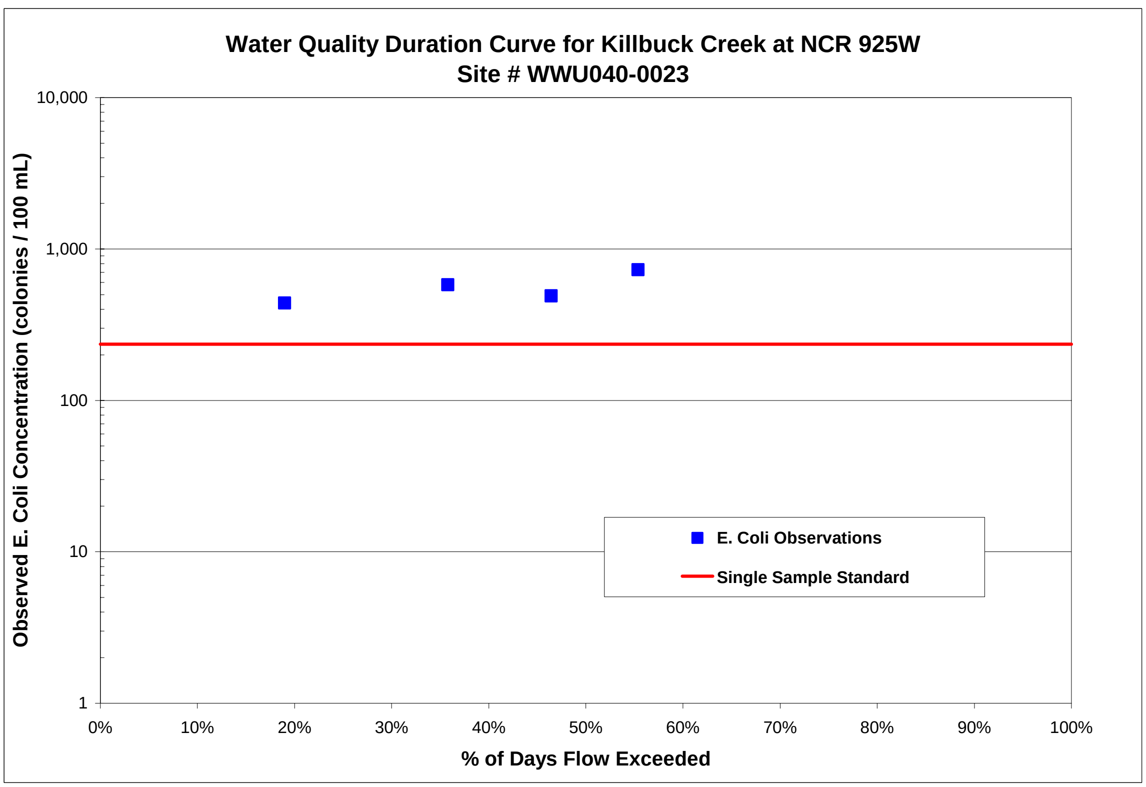


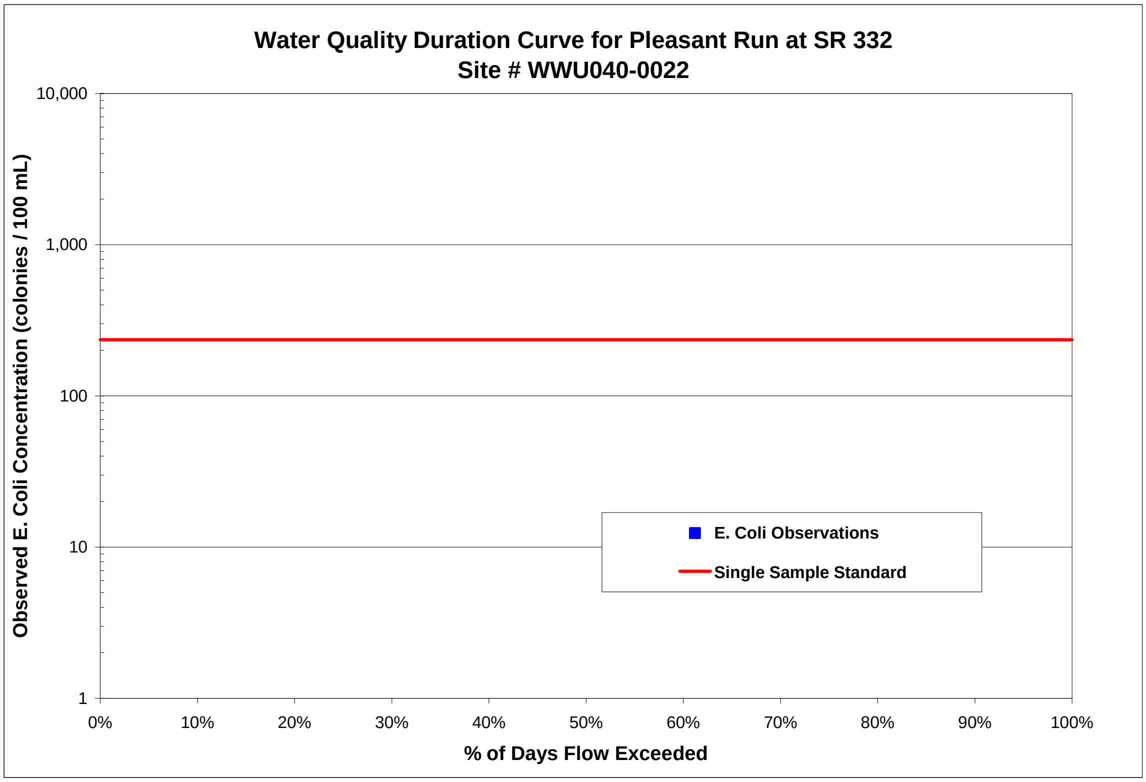
Water Quality Duration Curve for Killbuck Creek at SR 28/US 35
Site # WWU040-0026
10,000
1,000
100
10
1
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
Observed E. Coli Concentration (colonies / 100 mL)
% of Days Flow Exceeded
E. Coli Observations
Single Sample Standard

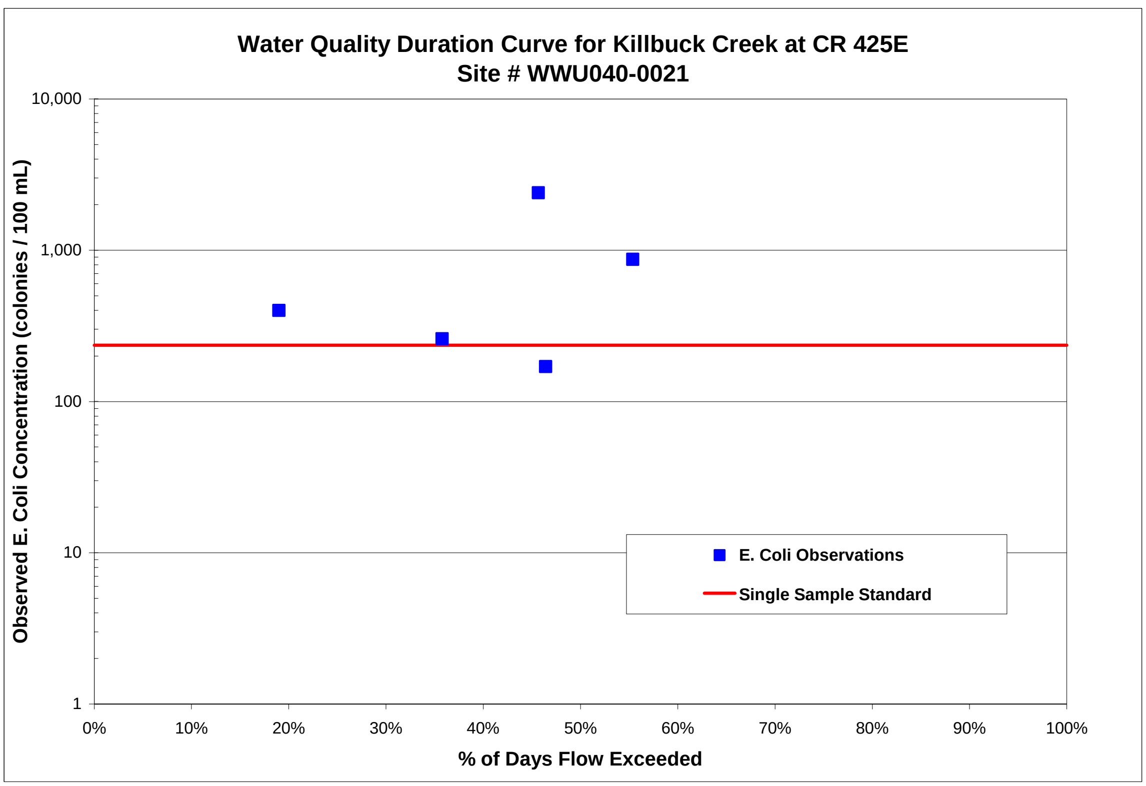


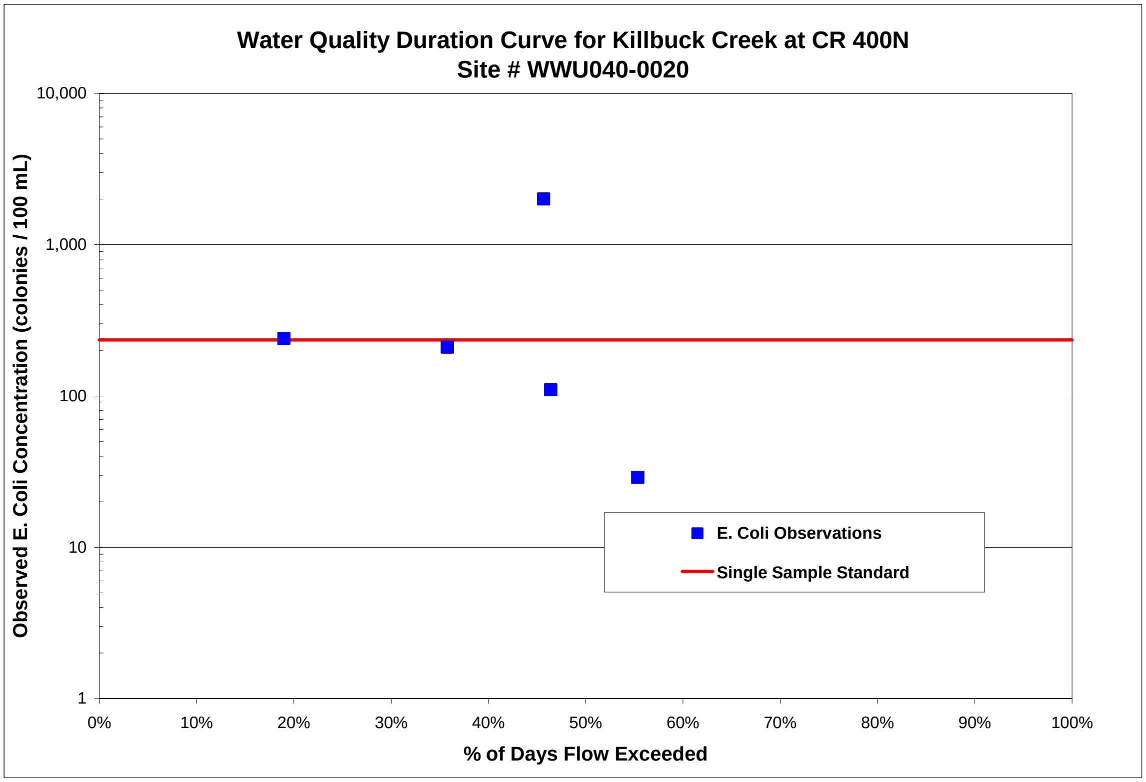
Water Quality Duration Curve for Killbuck Creek at CR 700W
Site # WWU040-0025
10,000
1,000
100
10
1
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
Observed E. Coli Concentration (colonies / 100 mL)
% of Days Flow Exceeded
E. Coli Observations
Single Sample Standard


Water Quality Duration Curve for Jakes Creek at CR 750W
Site # WWU040-0024
Observed E. Coli Concentration (colonies / 100 mL)
10,000
1,000
100
10
1
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
% of Days Flow Exceeded
E. Coli Observations
Single Sample Standard

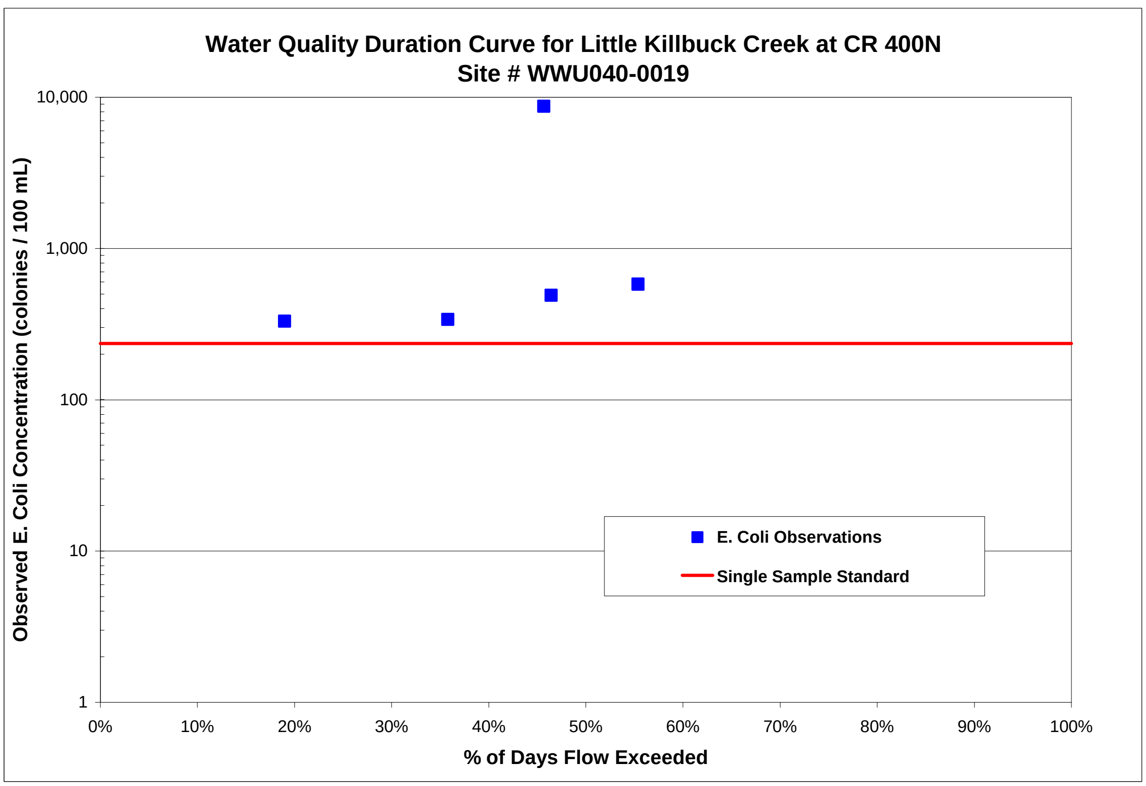

Water Quality Duration Curve for Killbuck Creek at NCR 925W
Site # WWU040-0023
Observed E. Coli Concentration (colonies / 100 mL)
10,000
1,000
100
10
1
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
% of Days Flow Exceeded
E. Coli Observations
Single Sample Standard


Water Quality Duration Curve for Pleasant Run at SR 332
Site # WWU040-0022
10,000
1,000
100
10
1
Observed E. Coli Concentration (colonies / 100 mL)
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
% of Days Flow Exceeded
E. Coli Observations
Single Sample Standard

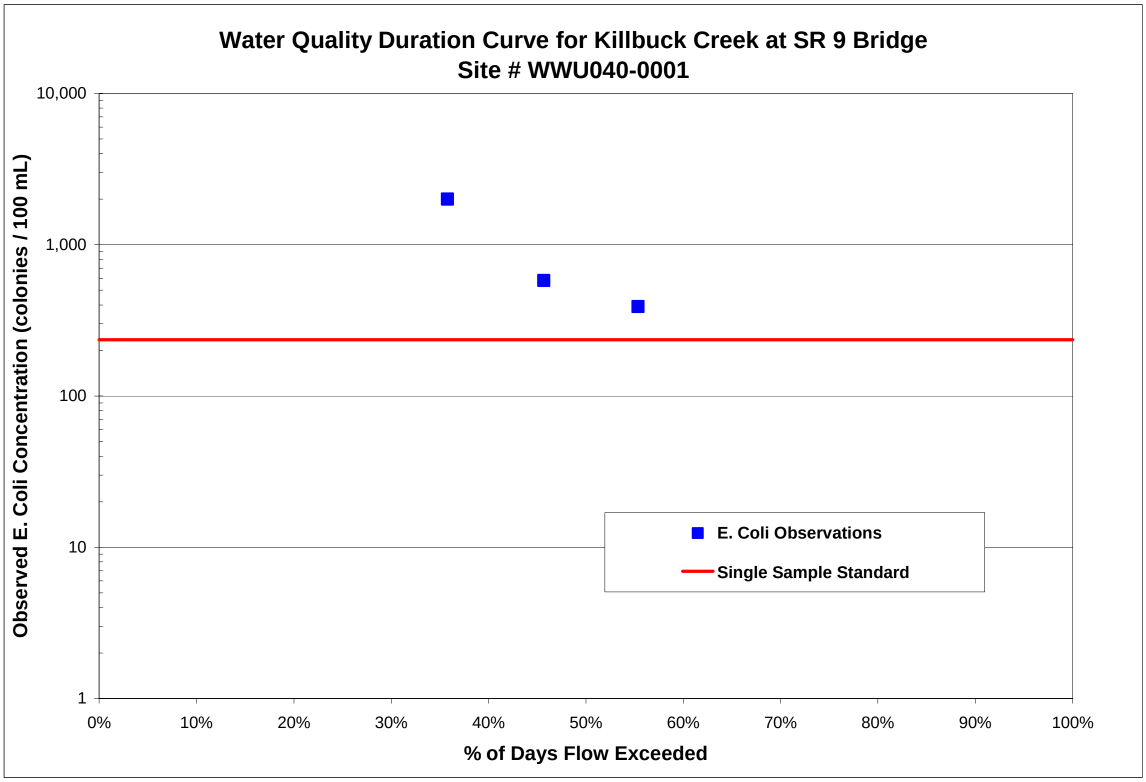

Water Quality Duration Curve for Killbuck Creek at CR 425E
Site # WWU040-0021
10,000
1,000
100
10
1
Observed E. Coli Concentration (colonies / 100 mL)
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
% of Days Flow Exceeded
E. Coli Observations
Single Sample Standard

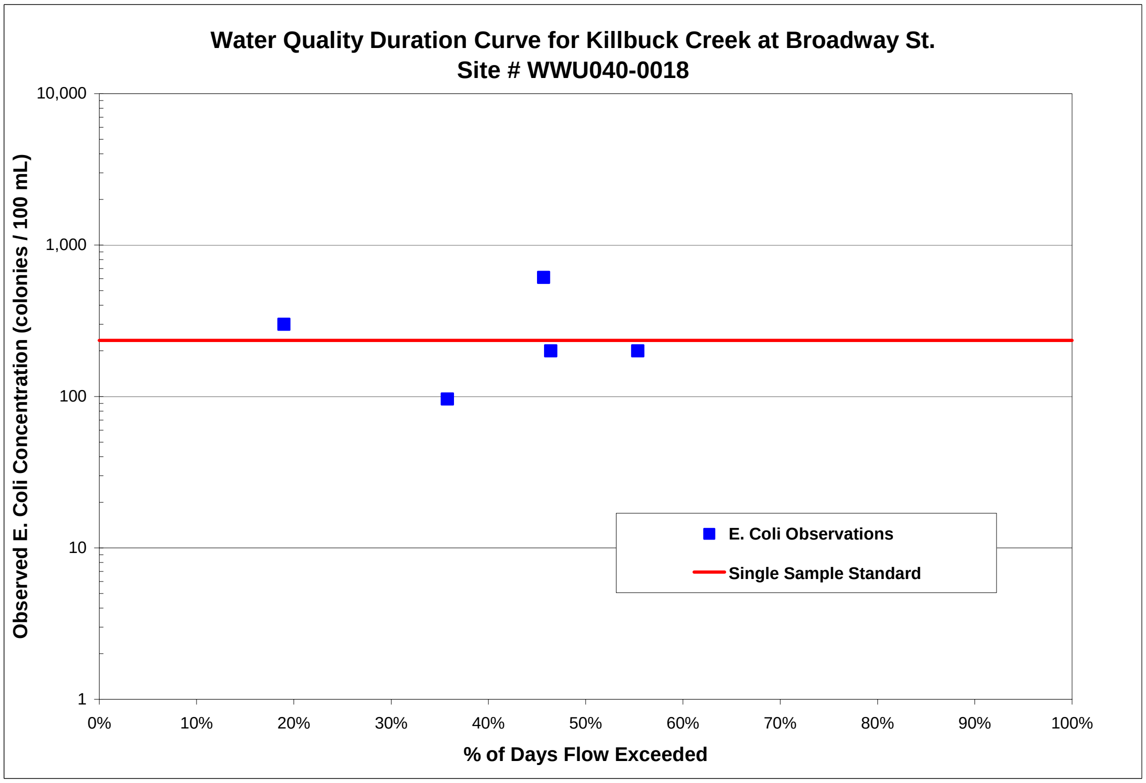


Water Quality Duration Curve for Killbuck Creek at CR 400N
Site # WWU040-0020
10,000
1,000
100
10
1
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
% of Days Flow Exceeded
Observed E. Coli Concentration (colonies / 100 mL)
E. Coli Observations
Single Sample Standard

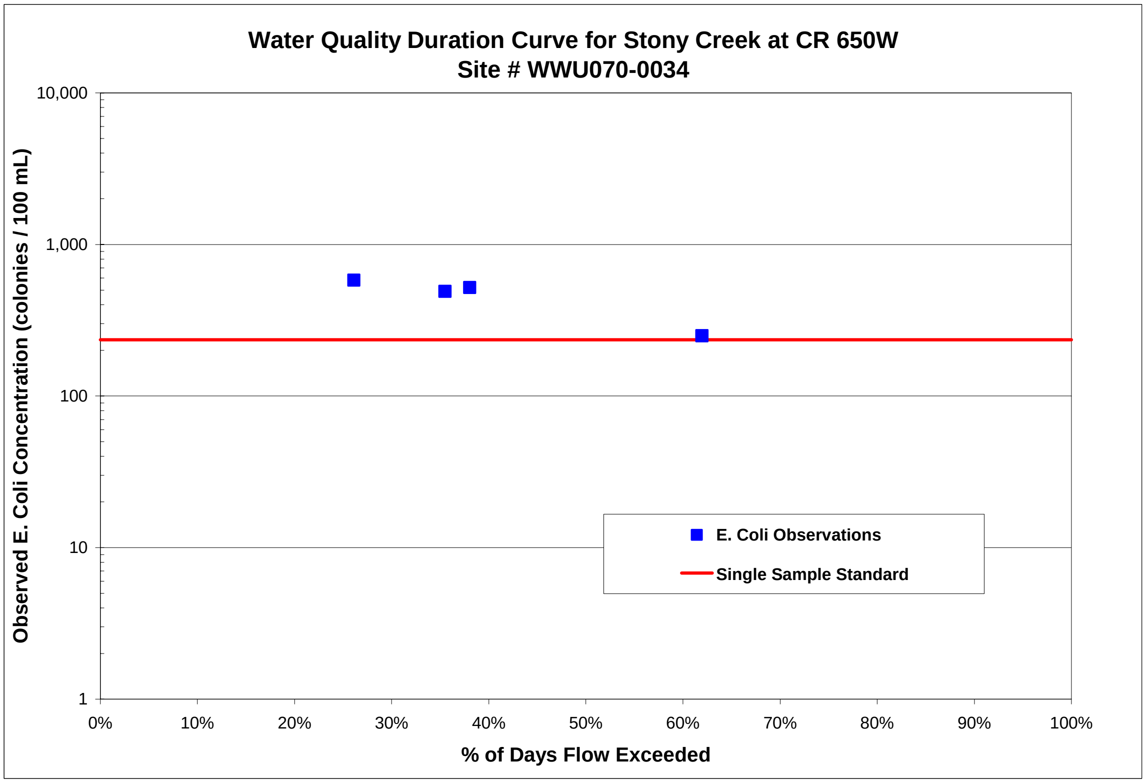


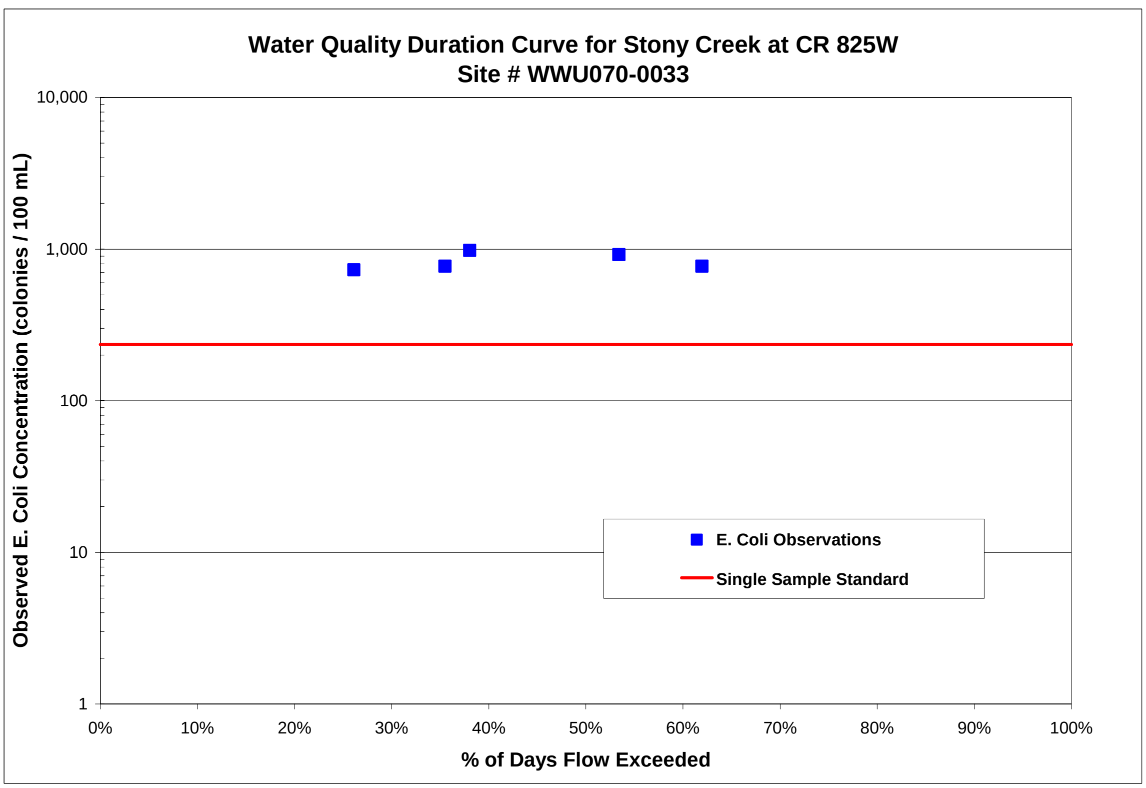
Water Quality Duration Curve for Little Killbuck Creek at CR 400N
Site # WWU040-0019
10,000
1,000
100
10
1
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
% of Days Flow Exceeded
Observed E. Coli Concentration (colonies / 100 mL)
E. Coli Observations
Single Sample Standard

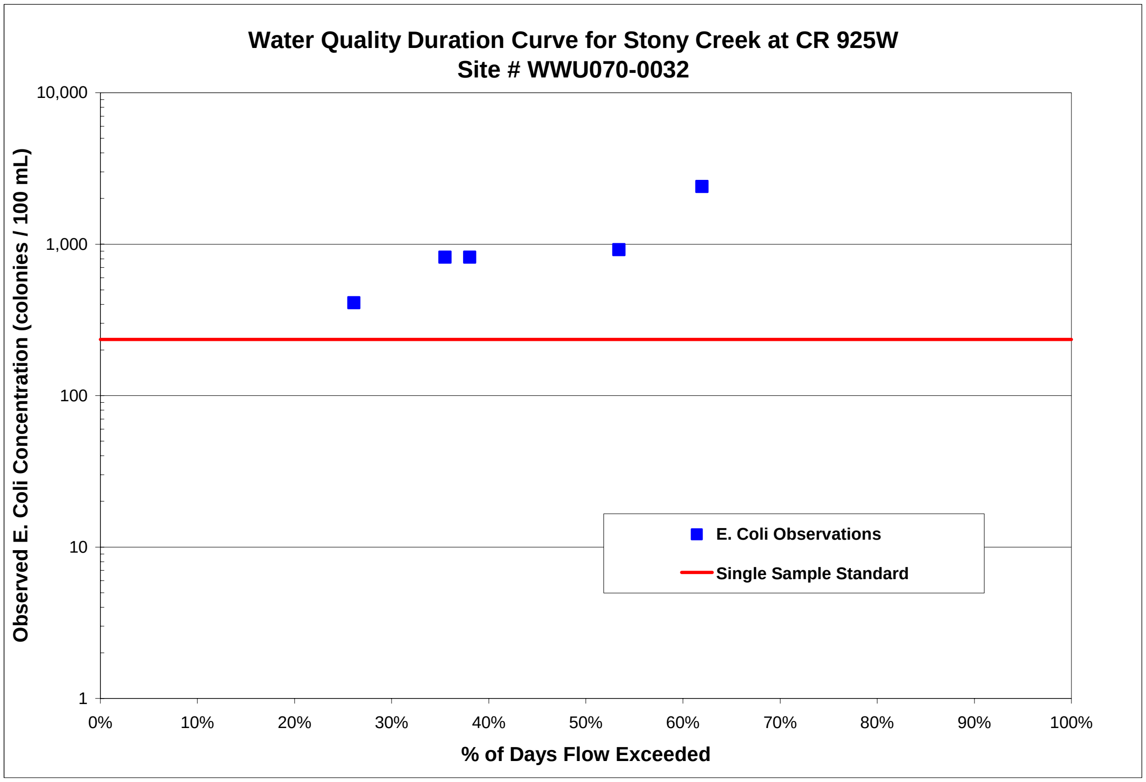

Water Quality Duration Curve for Killbuck Creek at SR 9 Bridge
Site # WWU040-0001
Observed E. Coli Concentration (colonies / 100 mL)
10,000
1,000
100
10
1
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
% of Days Flow Exceeded
E. Coli Observations
Single Sample Standard

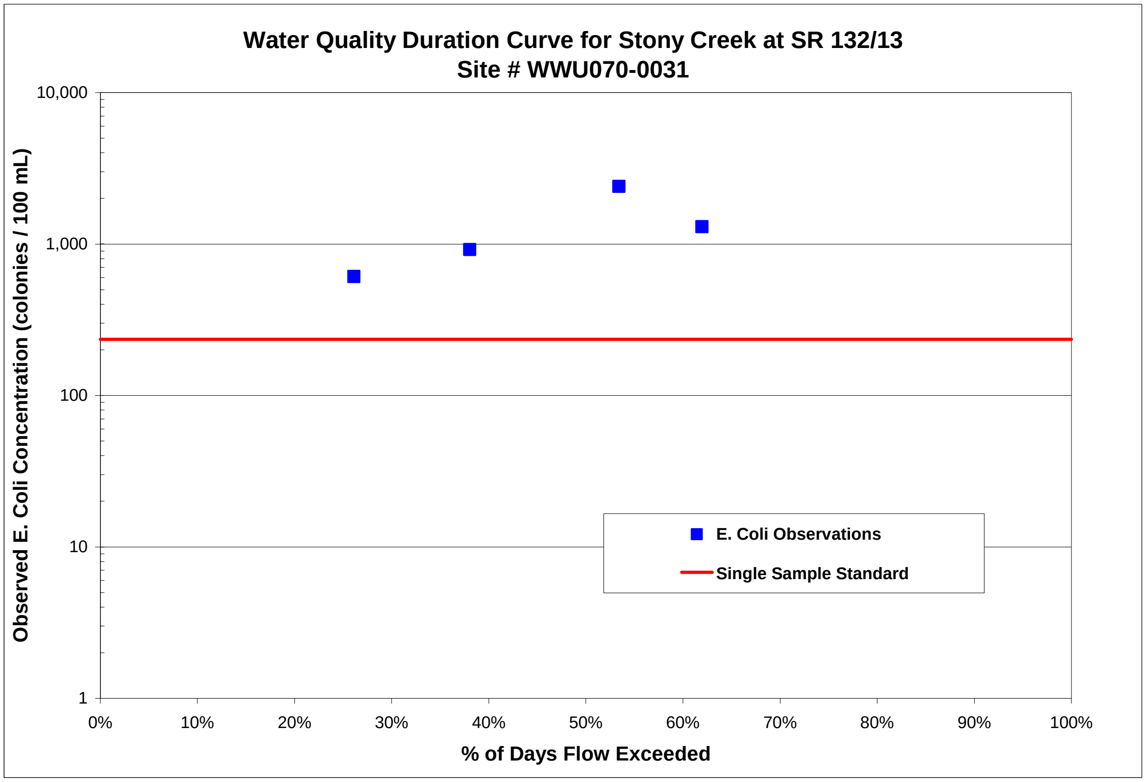

Water Quality Duration Curve for Killbuck Creek at Broadway St.
Site # WWU040-0018
Observed E. Coli Concentration (colonies / 100 mL)
10,000
1,000
100
10
1
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
% of Days Flow Exceeded
E. Coli Observations
Single Sample Standard

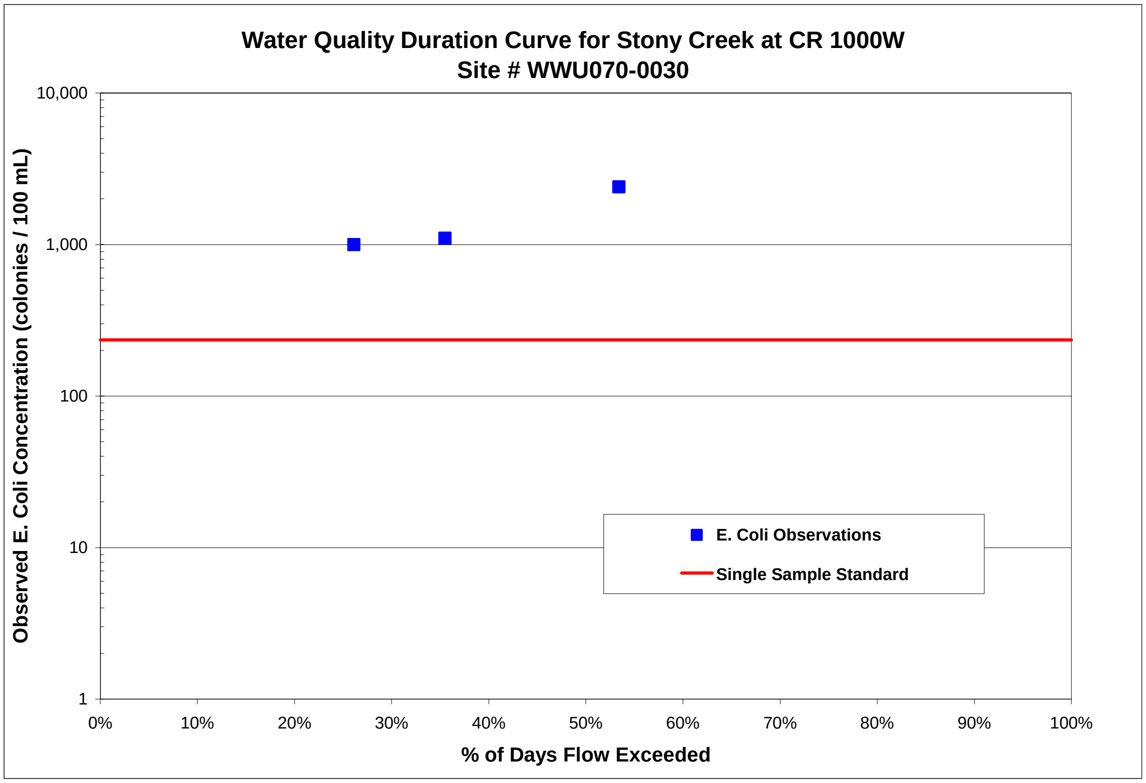
Water Quality Duration Curves for Stony Creek Watershed

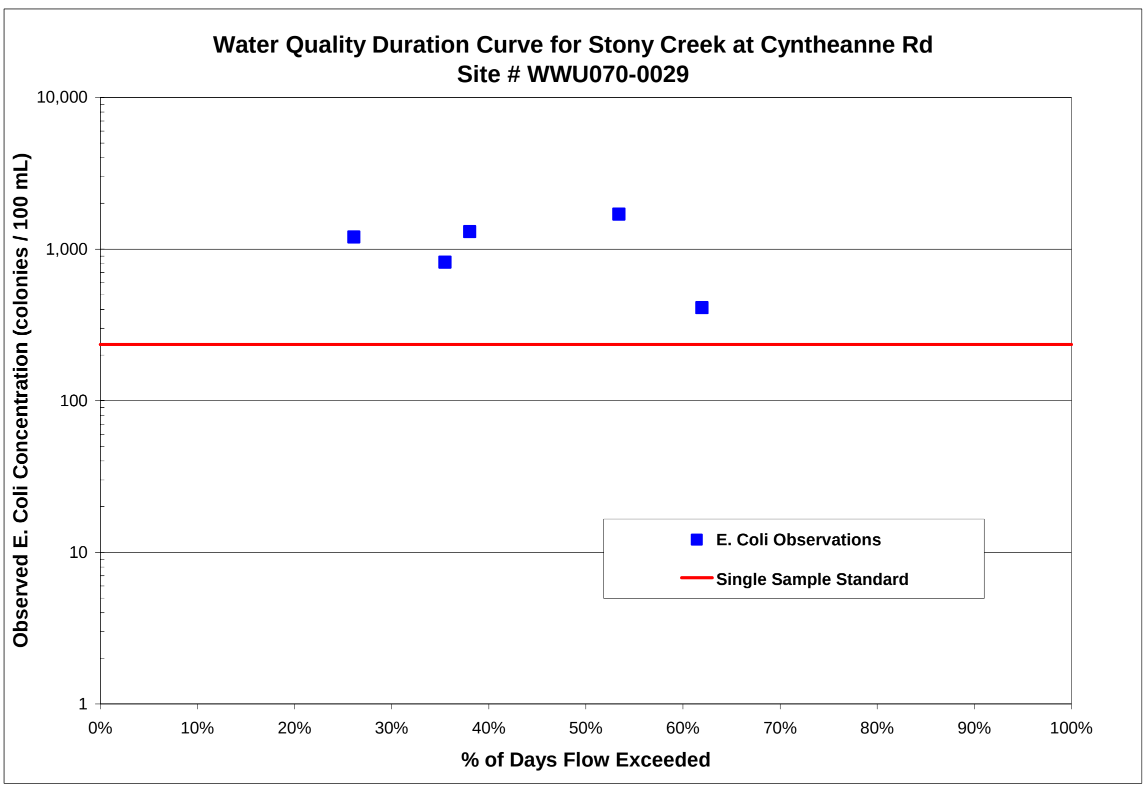


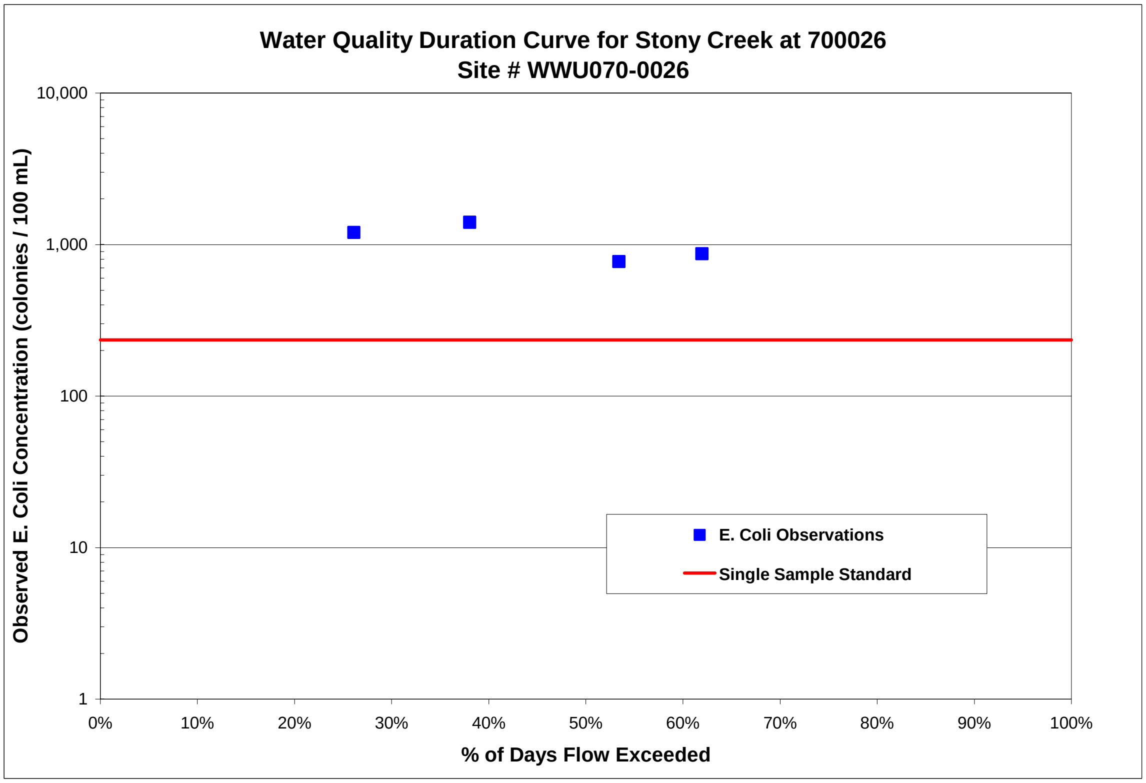



Water Quality Duration Curve for Stony Creek at CR 925W
Site # WWU070-0032
10,000
1,000
100
10
1
Observed E. Coli Concentration (colonies / 100 mL)
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
% of Days Flow Exceeded
E. Coli Observations
Single Sample Standard

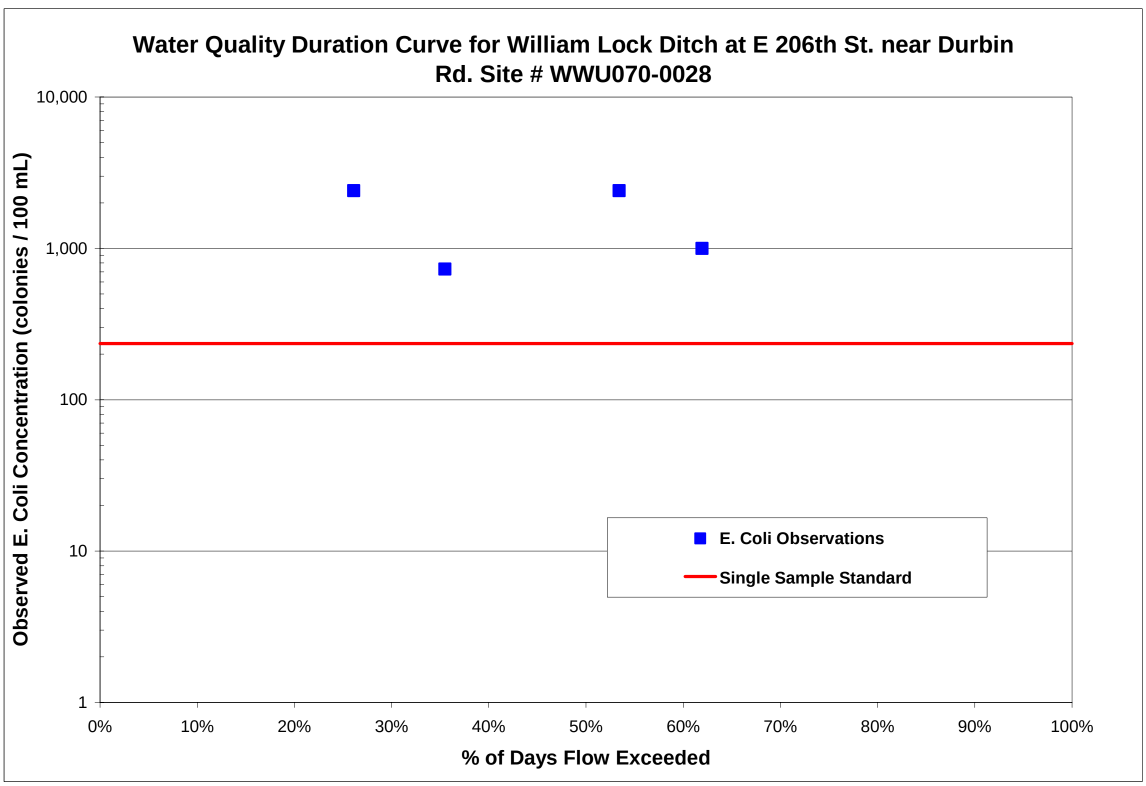

Water Quality Duration Curve for Stony Creek at SR 132/13
Site # WWU070-0031
10,000
1,000
100
10
1
Observed E. Coli Concentration (colonies / 100 mL)
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
% of Days Flow Exceeded
E. Coli Observations
Single Sample Standard


Water Quality Duration Curve for Stony Creek at CR 1000W
Site # WWU070-0030
Observed E. Coli Concentration (colonies / 100 mL)
10,000
1,000
100
10
1
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
% of Days Flow Exceeded
E. Coli Observations
Single Sample Standard

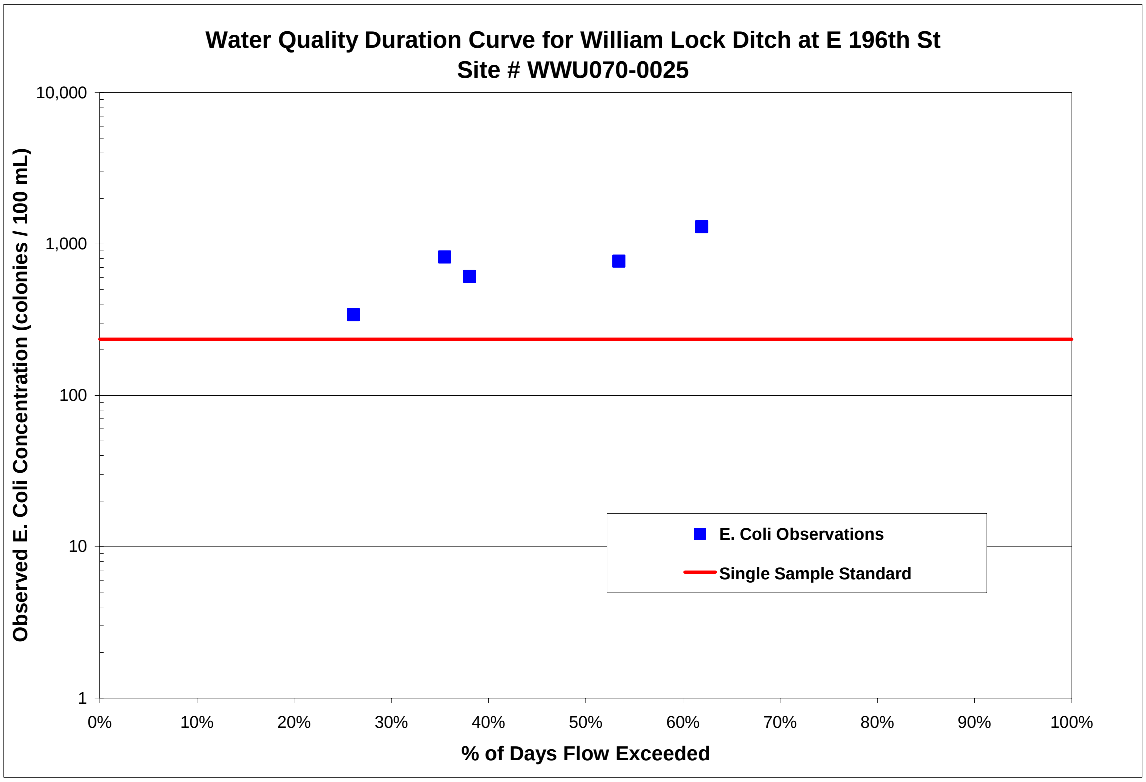

Water Quality Duration Curve for Stony Creek at Cyntheanne Rd
Site # WWU070-0029
Observed E. Coli Concentration (colonies / 100 mL)
10,000
1,000
100
10
1
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
% of Days Flow Exceeded
E. Coli Observations
Single Sample Standard

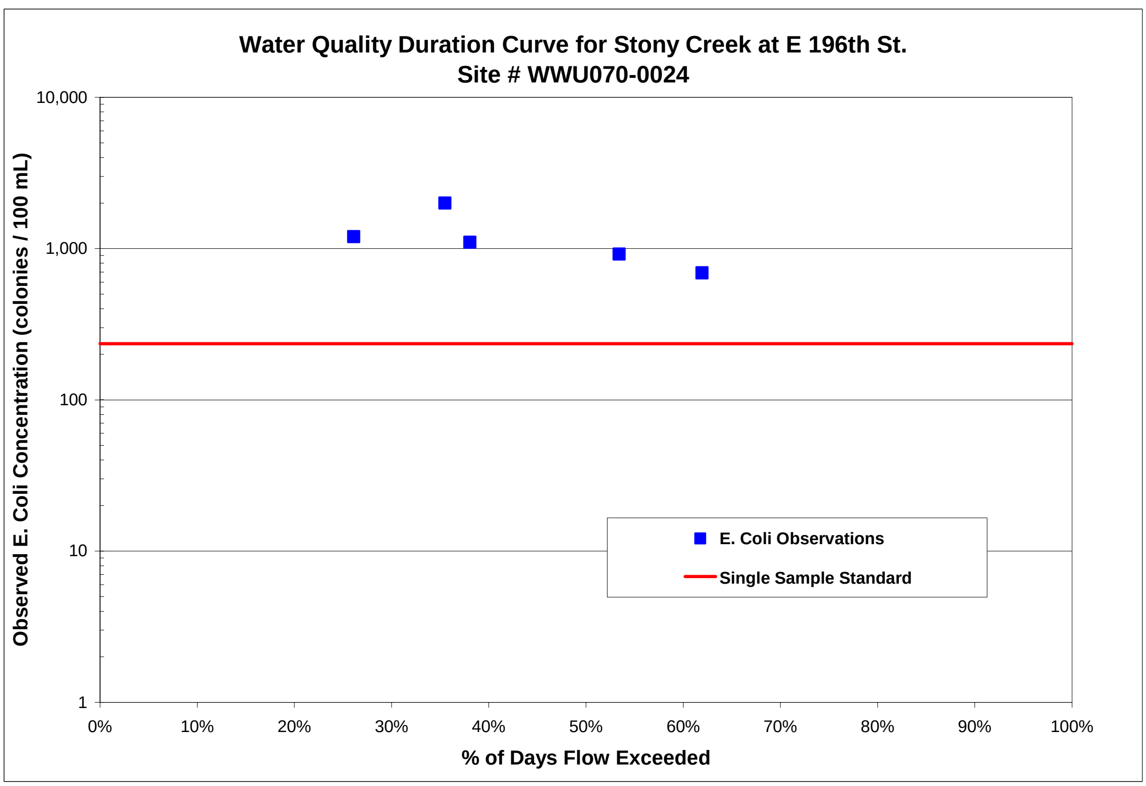


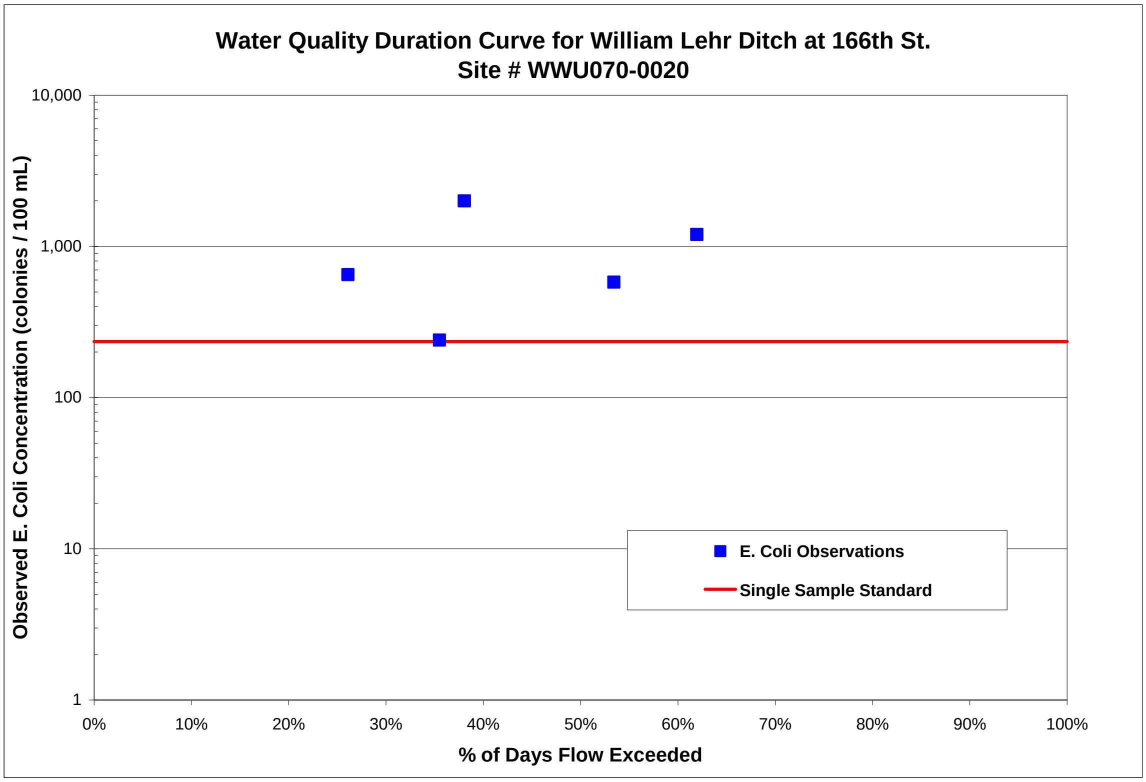
Water Quality Duration Curve for Stony Creek at 700026
Site # WWU070-0026
Observed E. Coli Concentration (colonies / 100 mL)
10,000
1,000
100
10
1
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
% of Days Flow Exceeded
E. Coli Observations
Single Sample Standard

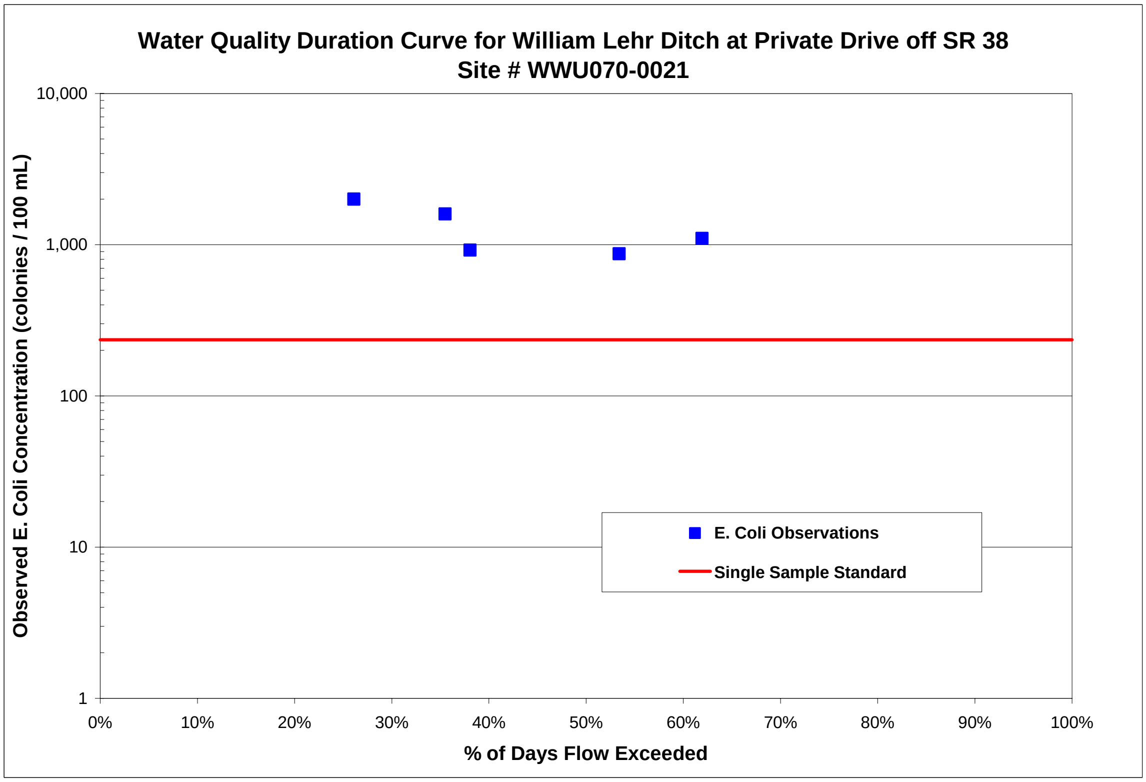


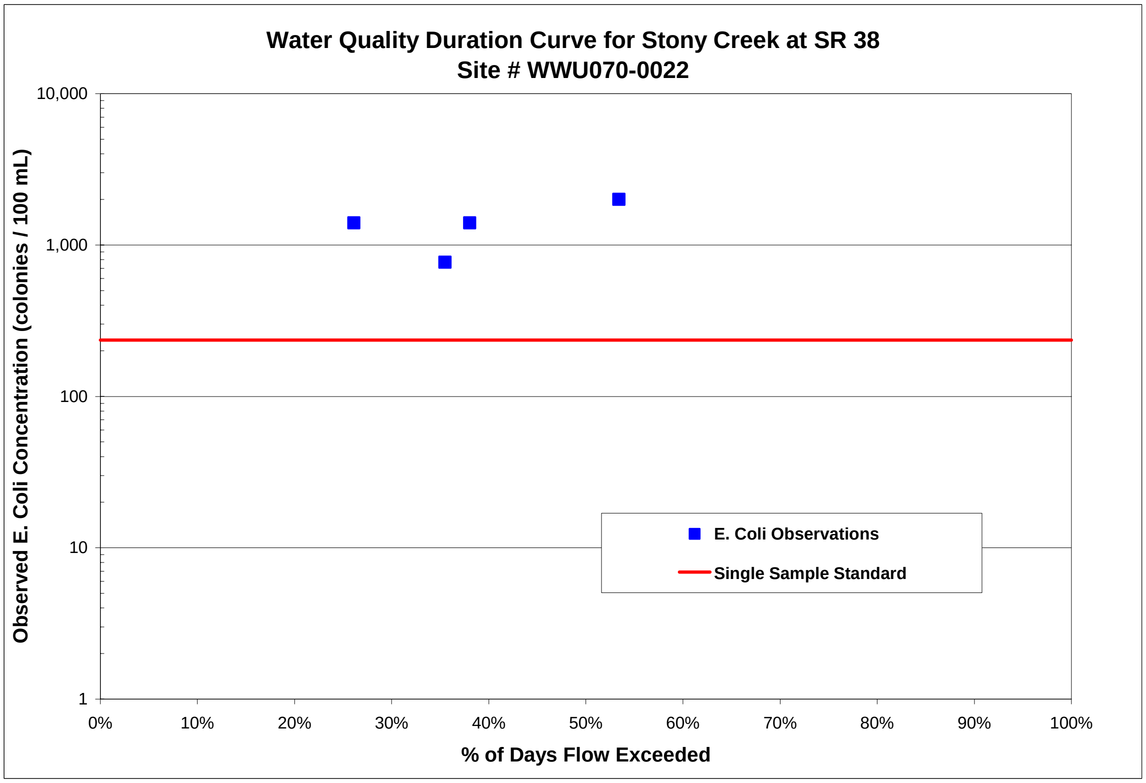
Water Quality Duration Curve for William Lock Ditch at E 206th St. near Durbin Rd. Site # WWU070-0028
Observed E. Coli Concentration (colonies / 100 mL)
10,000
1,000
100
10
1
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
% of Days Flow Exceeded
E. Coli Observations
Single Sample Standard

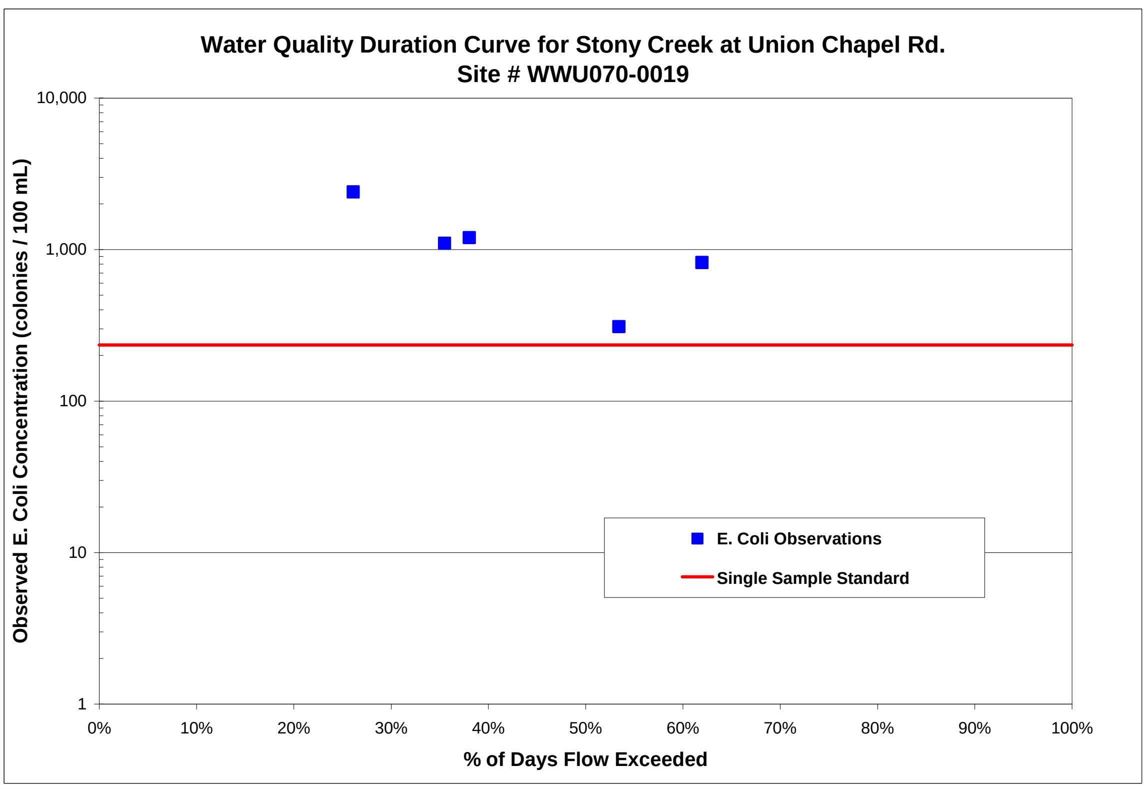

Water Quality Duration Curve for William Lock Ditch at E 196th St
Site # WWU070-0025
Observed E. Coli Concentration (colonies / 100 mL)
10,000
1,000
100
10
1
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
% of Days Flow Exceeded
E. Coli Observations
Single Sample Standard

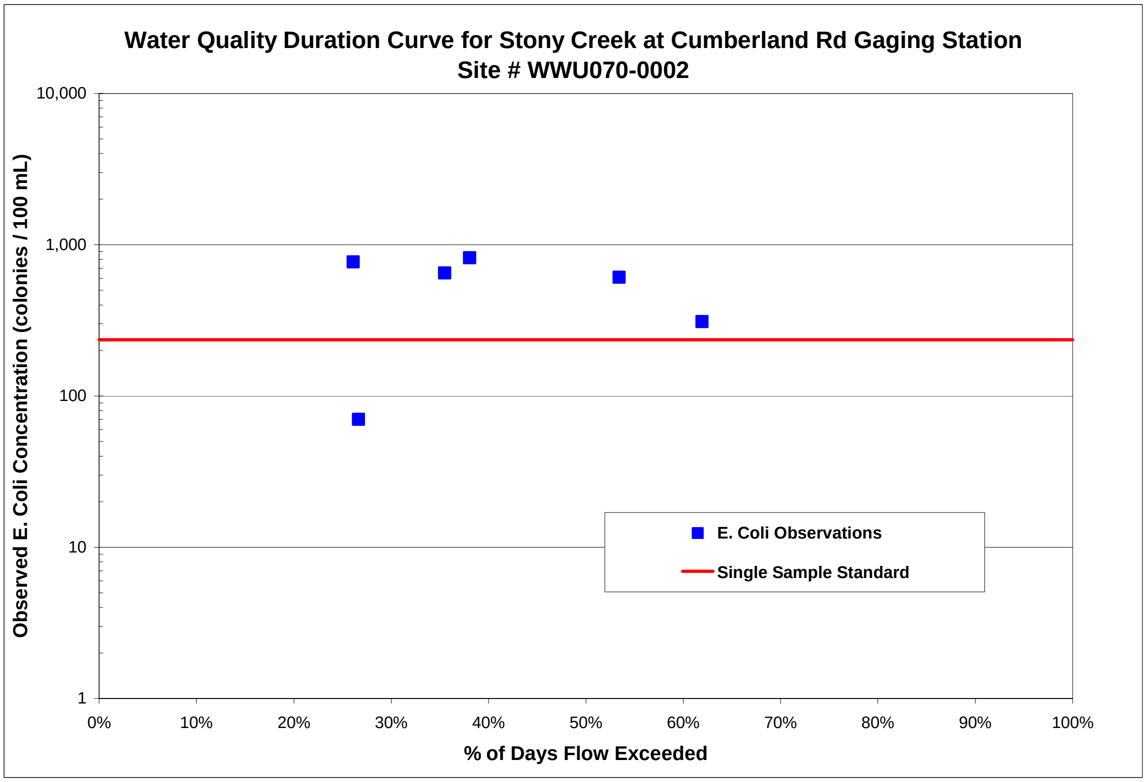

Water Quality Duration Curve for Stony Creek at E 196th St.
Site # WWU070-0024
Observed E. Coli Concentration (colonies / 100 mL)
10,000
1,000
100
10
1
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
% of Days Flow Exceeded
E. Coli Observations
Single Sample Standard

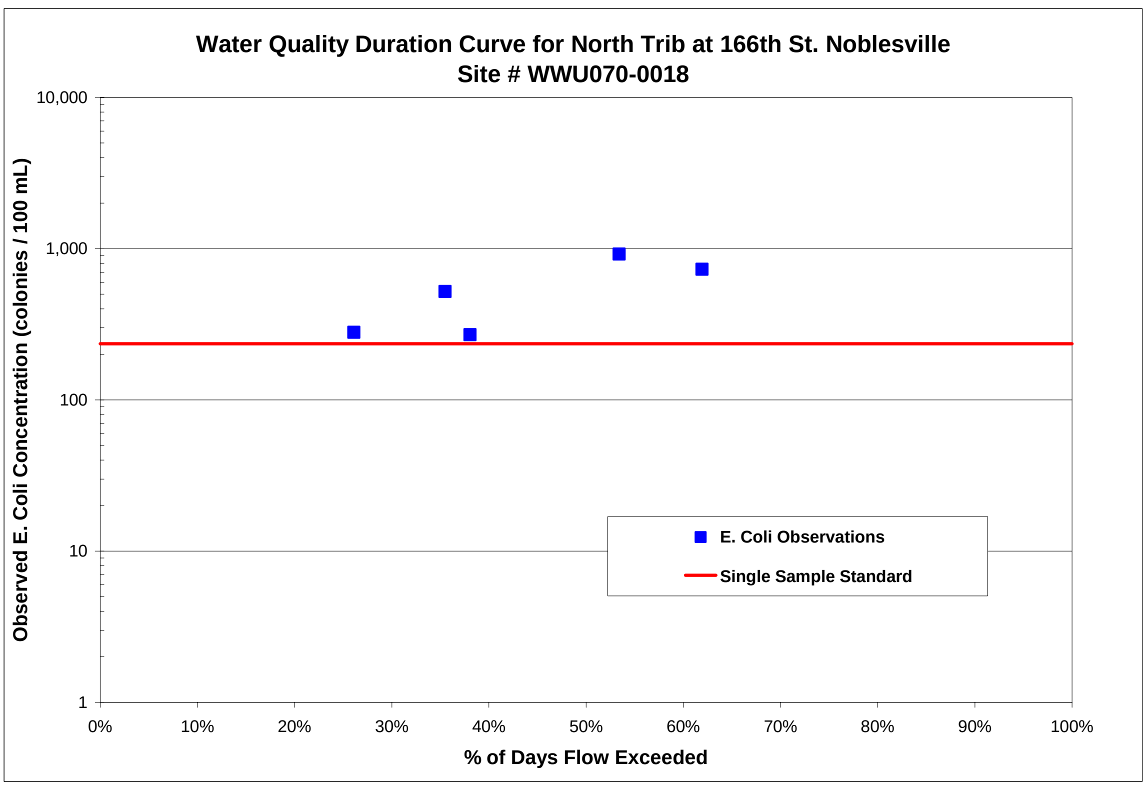

Water Quality Duration Curve for William Lehr Ditch at 166th St.
Site # WWU070-0020
10,000
1,000
100
10
1
Observed E. Coli Concentration (colonies / 100 mL)
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
% of Days Flow Exceeded
E. Coli Observations
Single Sample Standard

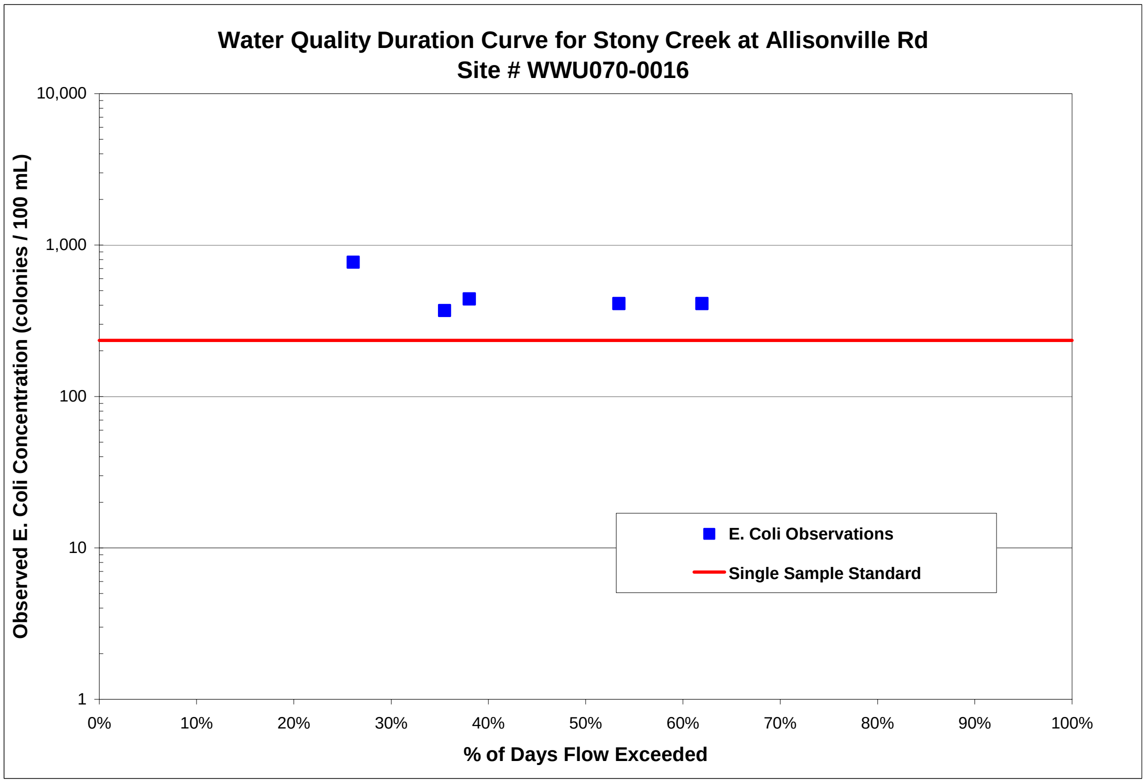

Water Quality Duration Curve for William Lehr Ditch at Private Drive off SR 38
Site # WWU070-0021
10,000
1,000
100
10
1
Observed E. Coli Concentration (colonies / 100 mL)
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
% of Days Flow Exceeded
E. Coli Observations
Single Sample Standard


Water Quality Duration Curve for Stony Creek at SR 38
Site # WWU070-0022
Observed E. Coli Concentration (colonies / 100 mL)
10,000
1,000
100
10
1
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
% of Days Flow Exceeded
E. Coli Observations
Single Sample Standard


Water Quality Duration Curve for Stony Creek at Union Chapel Rd.
Site # WWU070-0019
Observed E. Coli Concentration (colonies / 100 mL)
10,000
1,000
100
10
1
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
% of Days Flow Exceeded
E. Coli Observations
Single Sample Standard


Water Quality Duration Curve for Stony Creek at Cumberland Rd Gaging Station
Site # WWU070-0002
Observed E. Coli Concentration (colonies / 100 mL)
10,000
1,000
100
10
1
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
% of Days Flow Exceeded
E. Coli Observations
Single Sample Standard


Water Quality Duration Curve for North Trib at 166th St. Noblesville
Site # WWU070-0018
Observed E. Coli Concentration (colonies / 100 mL)
10,000
1,000
100
10
1
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
% of Days Flow Exceeded
E. Coli Observations
Single Sample Standard

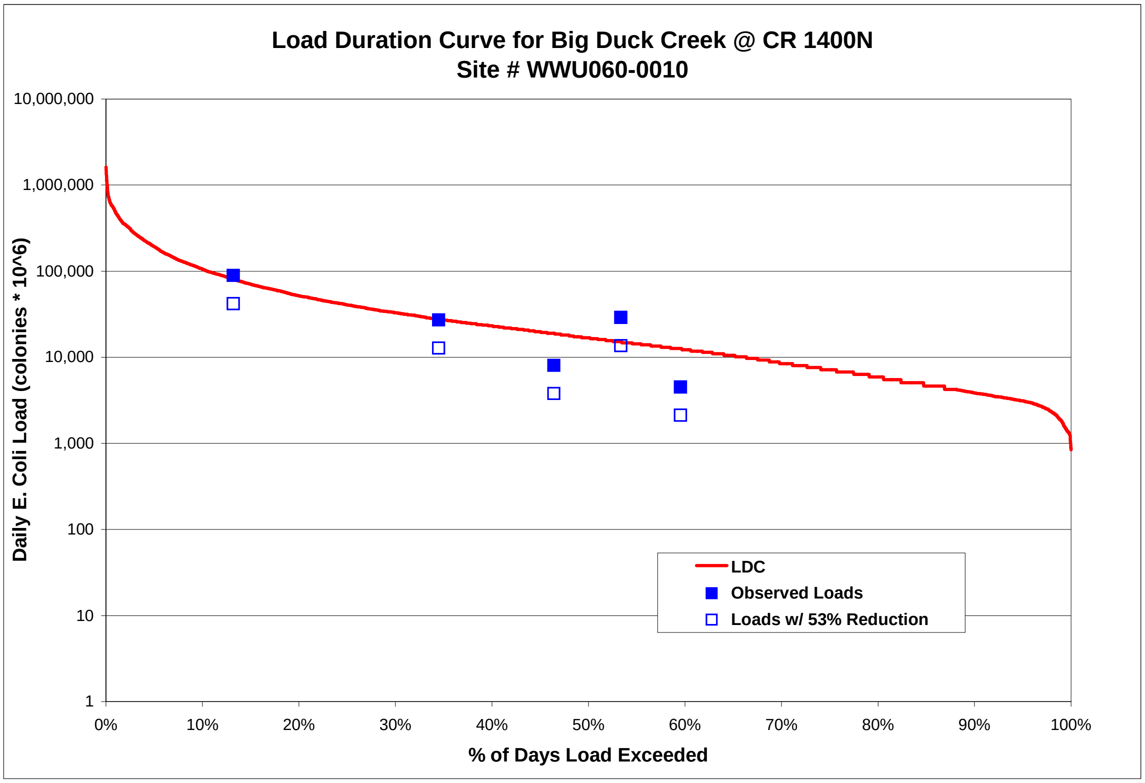


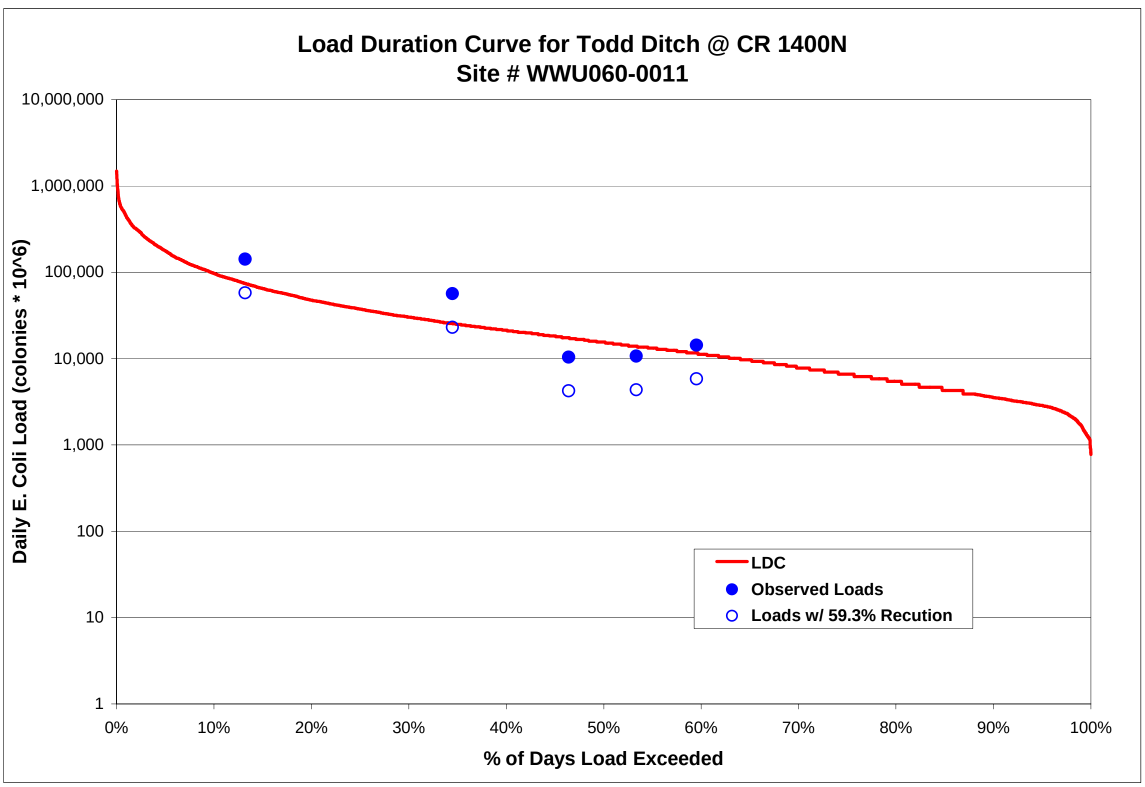
Water Quality Duration Curve for Stony Creek at Allisonville Rd
Site # WWU070-0016
Observed E. Coli Concentration (colonies / 100 mL)
10,000
1,000
100
10
1
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
% of Days Flow Exceeded
E. Coli Observations
Single Sample Standard

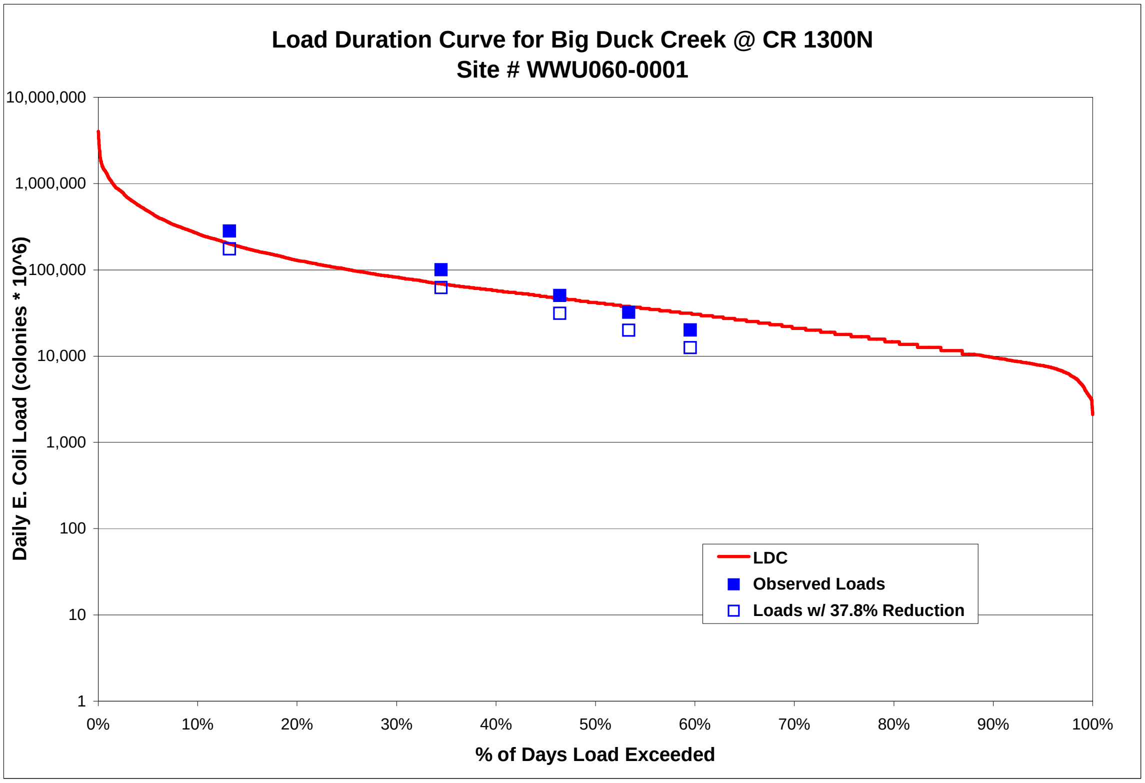
APPENDIX C

LOAD DURATION CURVES

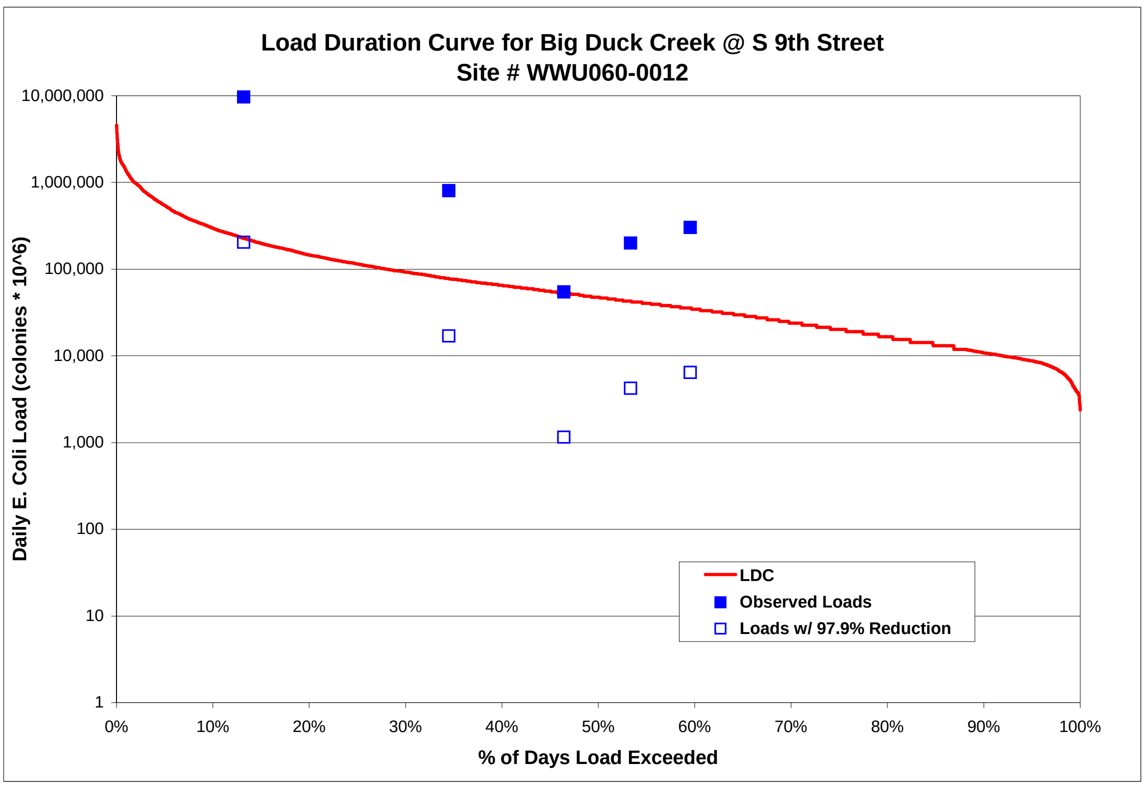
Load Duration Curves for Duck Creek Watershed



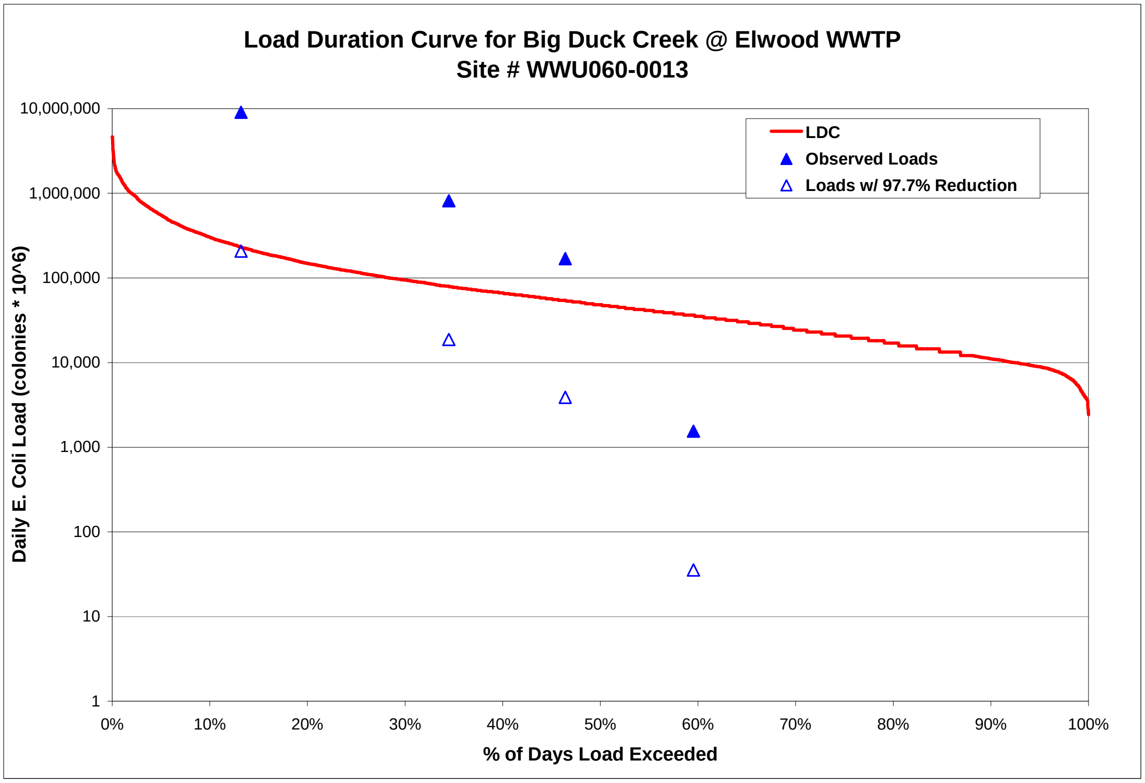


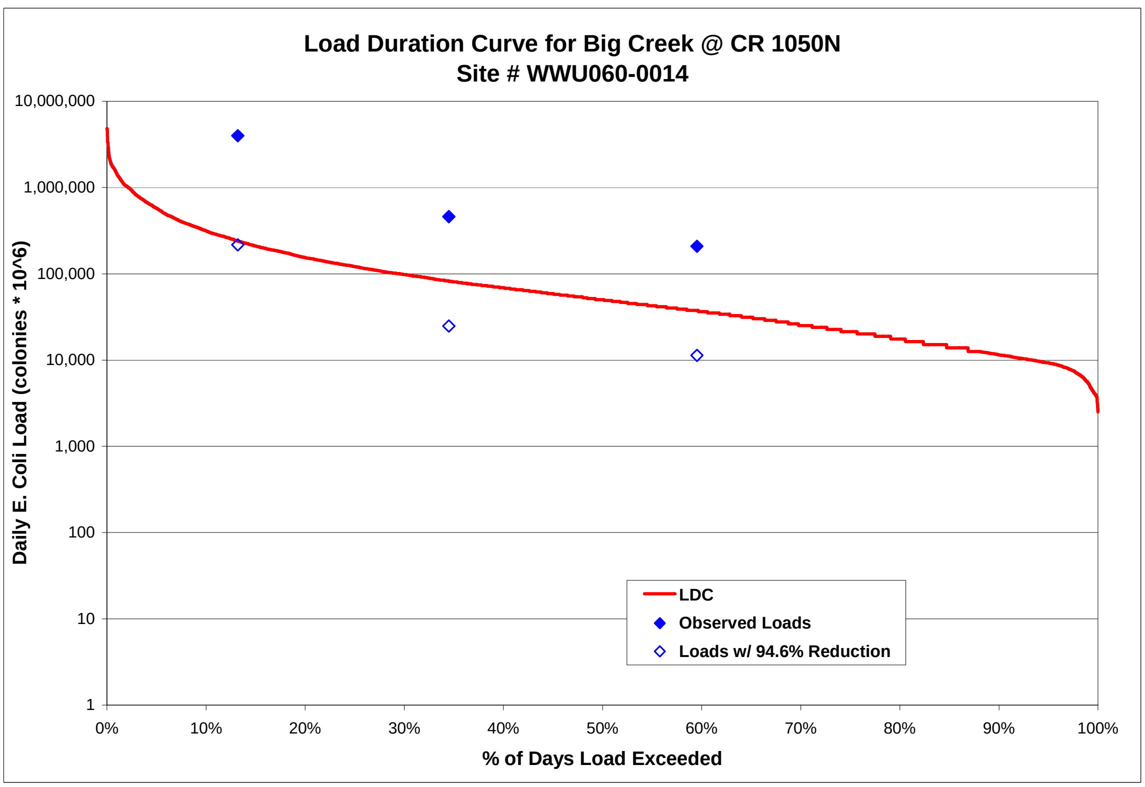


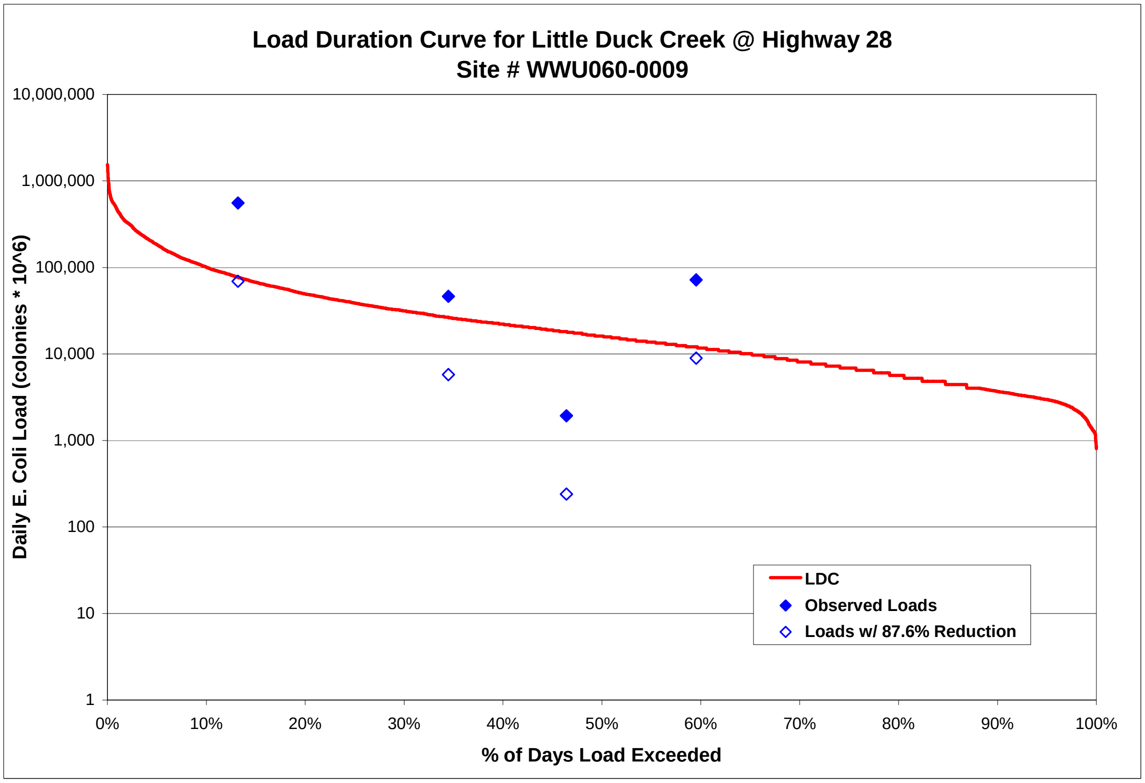
Load Duration Curve for Big Duck Creek @ CR 1300N
Site # WWU060-0001
Daily E. Coli Load (colonies * 10^6)
10,000,000
1,000,000
100,000
10,000
1,000
100
10
1
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
% of Days Load Exceeded
LDC
Observed Loads
Loads w/ 37.8% Reduction



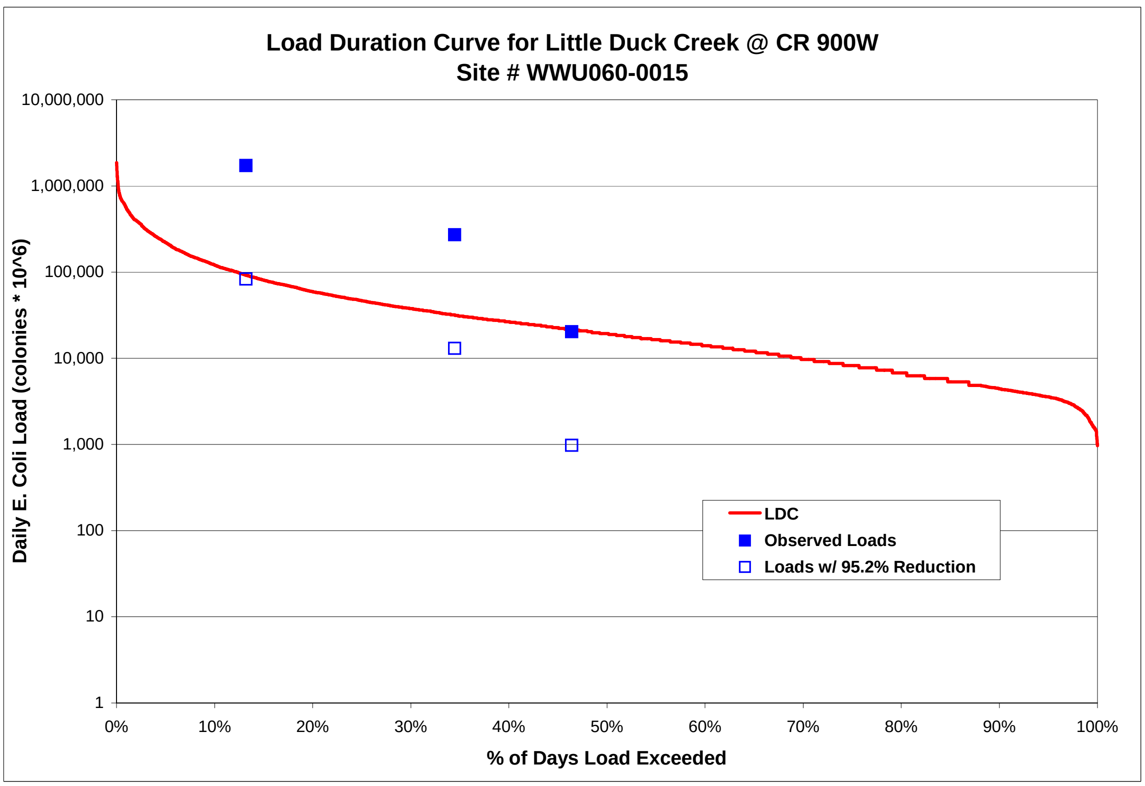
Load Duration Curve for Big Duck Creek @ S 9th Street
Site # WWU060-0012
Daily E. Coli Load (colonies * 10^6)
10,000,000
1,000,000
100,000
10,000
1,000
100
10
1
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
% of Days Load Exceeded
LDC
Observed Loads
Loads w/ 97.9% Reduction


Load Duration Curve for Big Duck Creek @ Elwood WWTP
Site # WWU060-0013
LDC
Observed Loads
Loads w/ 97.7% Reduction
Daily E. Coli Load (colonies * 10^6)
10,000,000
1,000,000
100,000
10,000
1,000
100
10
1
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
% of Days Load Exceeded

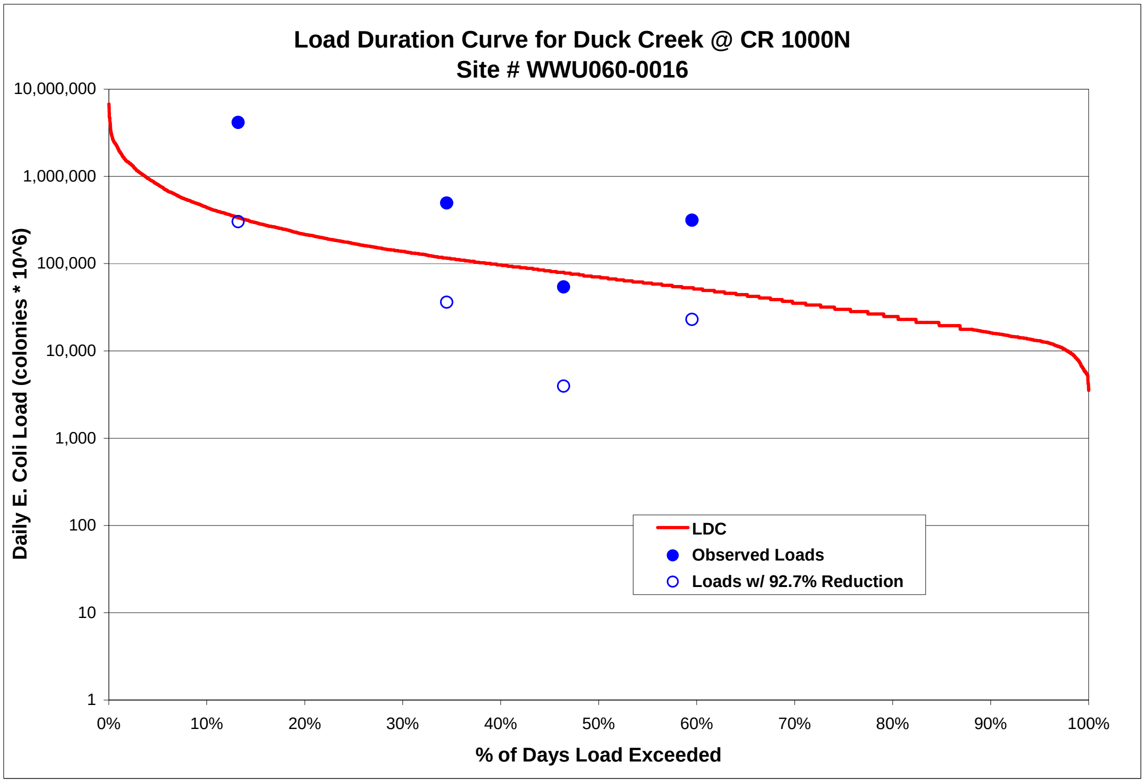

Load Duration Curve for Big Creek @ CR 1050N
Site # WWU060-0014
LDC
Observed Loads
Loads w/ 94.6% Reduction
Daily E. Coli Load (colonies * 10^6)
10,000,000
1,000,000
100,000
10,000
1,000
100
10
1
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
% of Days Load Exceeded

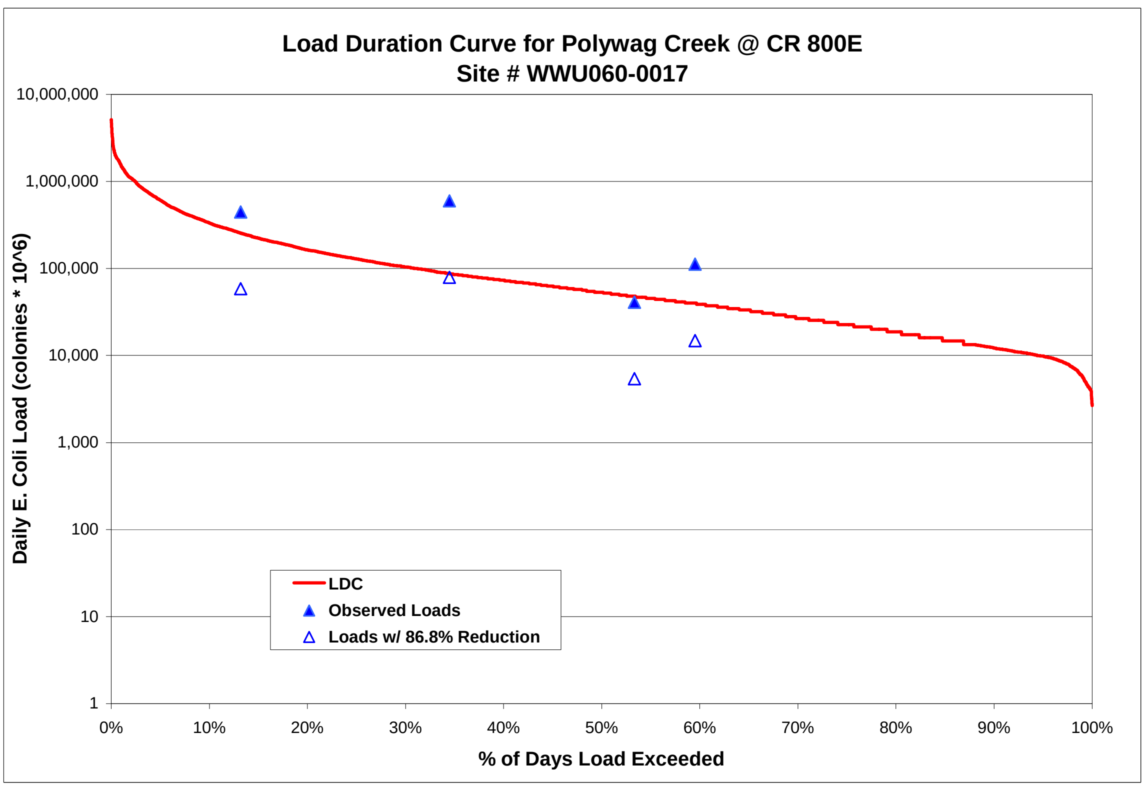


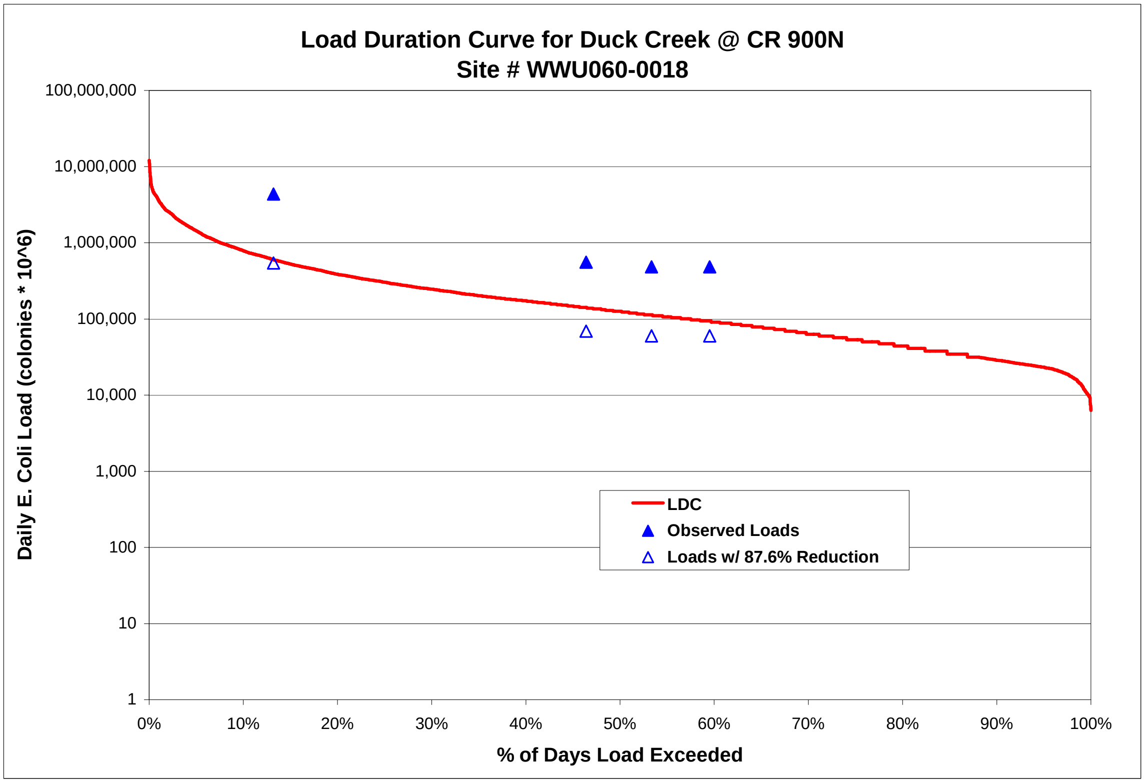
Load Duration Curve for Little Duck Creek @ Highway 28
Site # WWU060-0009
10,000,000
1,000,000
100,000
10,000
1,000
100
10
1
Daily E. Coli Load (colonies * 10^6)
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
% of Days Load Exceeded
LDC
Observed Loads
Loads w/ 87.6% Reduction

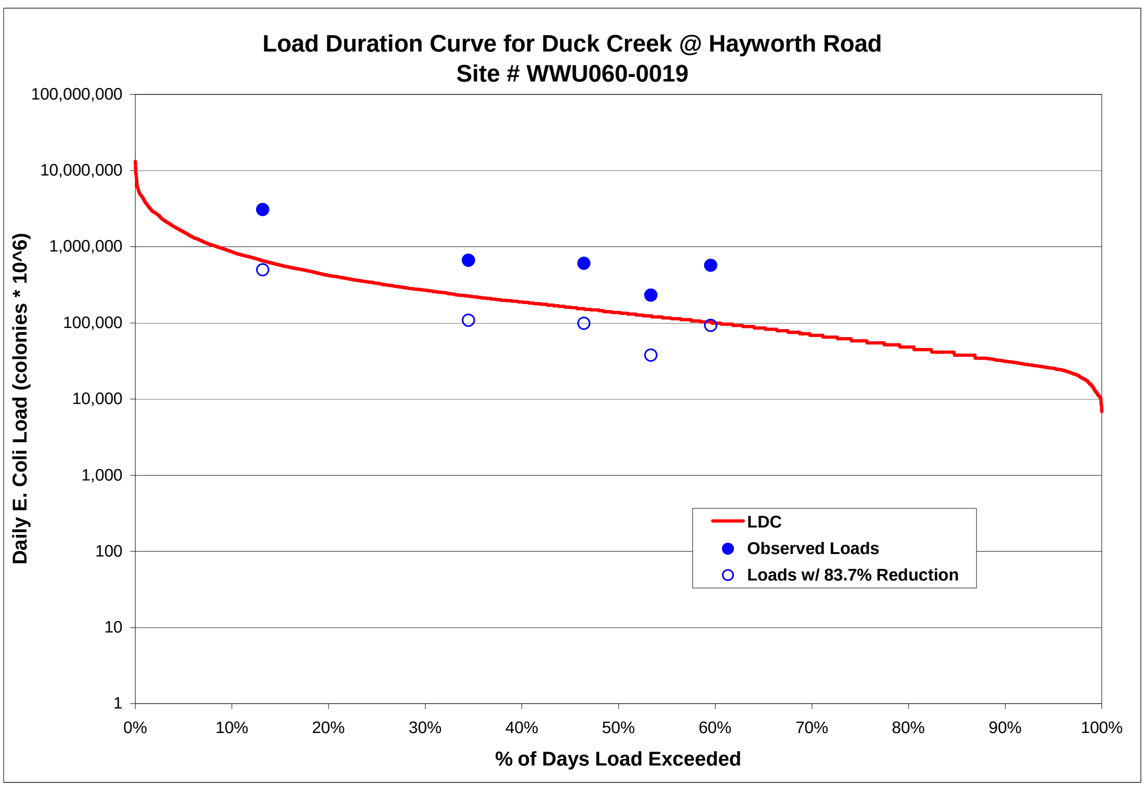


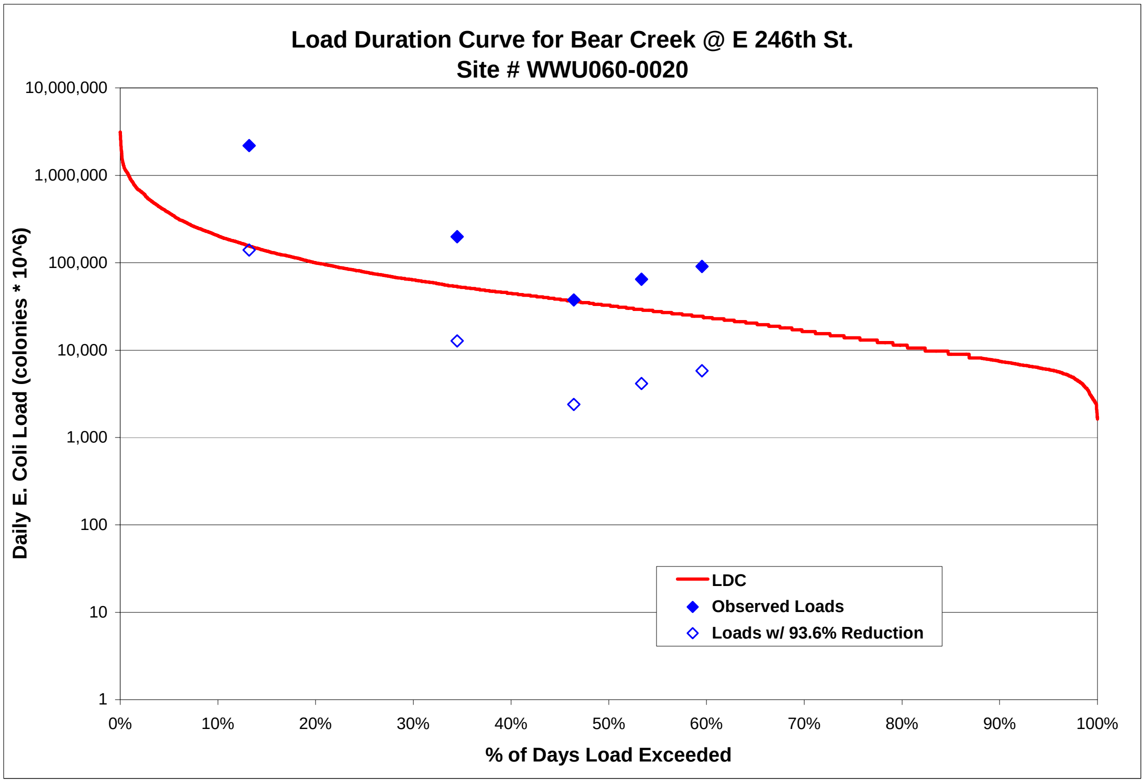
Load Duration Curve for Little Duck Creek @ CR 900W
Site # WWU060-0015
10,000,000
1,000,000
100,000
10,000
1,000
100
10
1
Daily E. Coli Load (colonies * 10^6)
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
% of Days Load Exceeded
LDC
Observed Loads
Loads w/ 95.2% Reduction

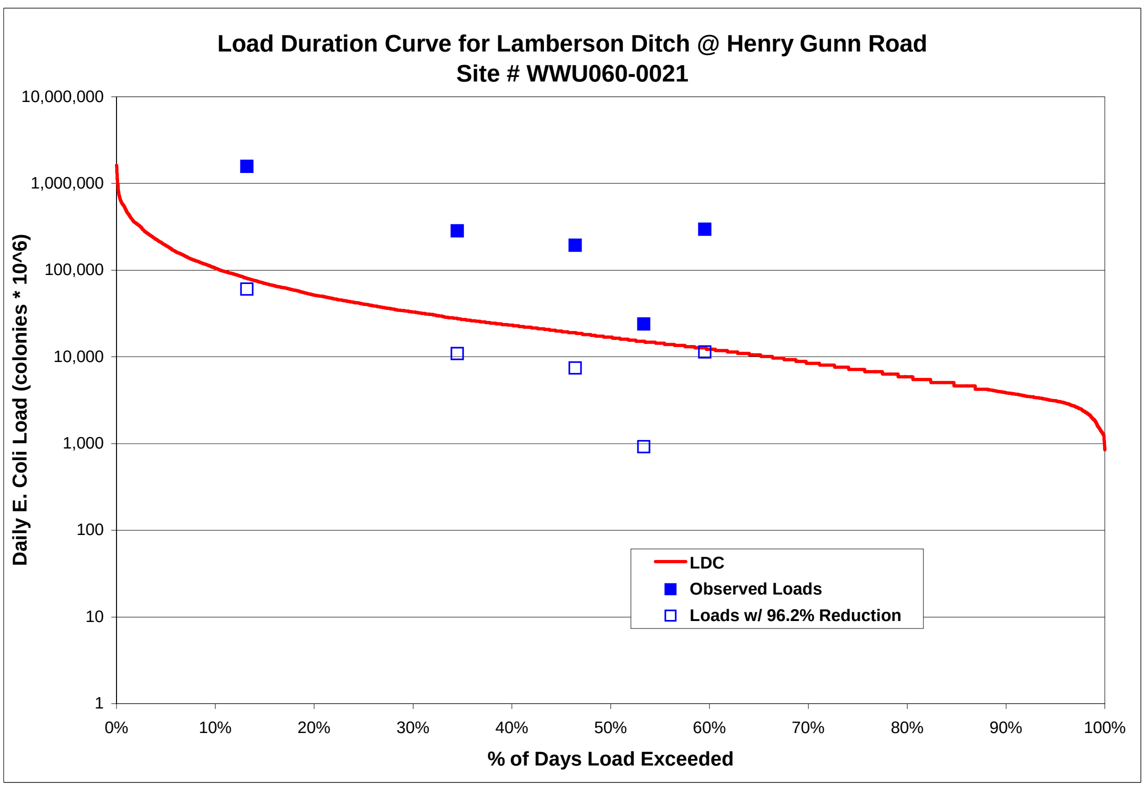

Load Duration Curve for Duck Creek @ CR 1000N
Site # WWU060-0016
Daily E. Coli Load (colonies * 10^6)
10,000,000
1,000,000
100,000
10,000
1,000
100
10
1
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
% of Days Load Exceeded
LDC
Observed Loads
Loads w/ 92.7% Reduction

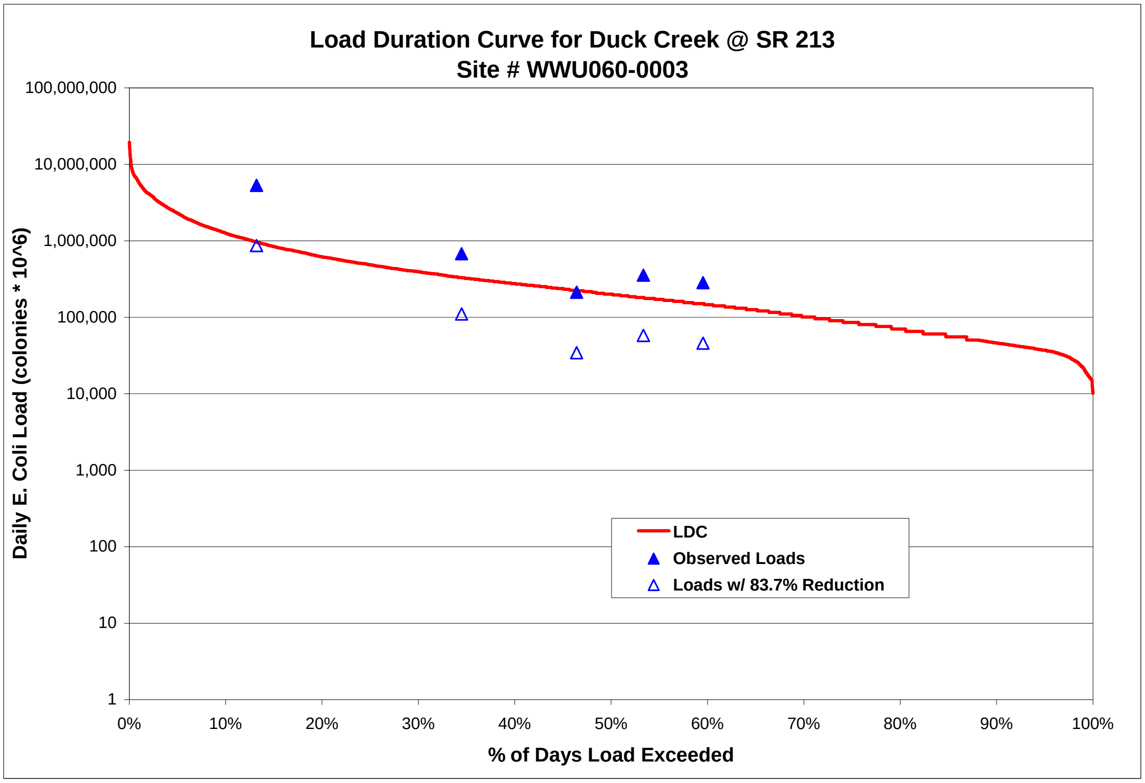

Load Duration Curve for Polywag Creek @ CR 800E
Site # WWU060-0017
Daily E. Coli Load (colonies * 10^6)
10,000,000
1,000,000
100,000
10,000
1,000
100
10
1
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
% of Days Load Exceeded
LDC
Observed Loads
Loads w/ 86.8% Reduction


Load Duration Curve for Duck Creek @ CR 900N
Site # WWU060-0018
Daily E. Coli Load (colonies * 10^6)
100,000,000
10,000,000
1,000,000
100,000
10,000
1,000
100
10
1
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
% of Days Load Exceeded
LDC
Observed Loads
Loads w/ 87.6% Reduction


Load Duration Curve for Duck Creek @ Hayworth Road
Site # WWU060-0019
Daily E. Coli Load (colonies * 10^6)
100,000,000
10,000,000
1,000,000
100,000
10,000
1,000
100
10
1
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
% of Days Load Exceeded
LDC
Observed Loads
Loads w/ 83.7% Reduction

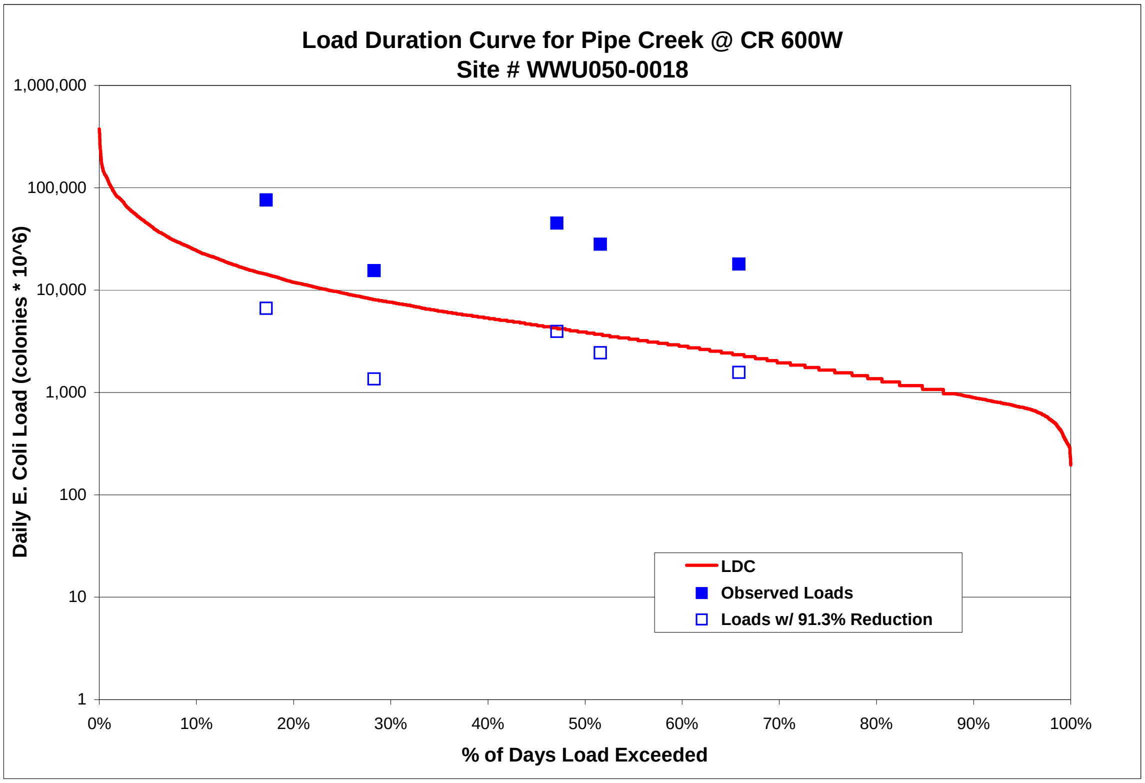

Load Duration Curve for Bear Creek @ E 246th St.
Site # WWU060-0020
10,000,000
1,000,000
100,000
10,000
1,000
100
10
1
Daily E. Coli Load (colonies * 10^6)
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
% of Days Load Exceeded
LDC
Observed Loads
Loads w/ 93.6% Reduction

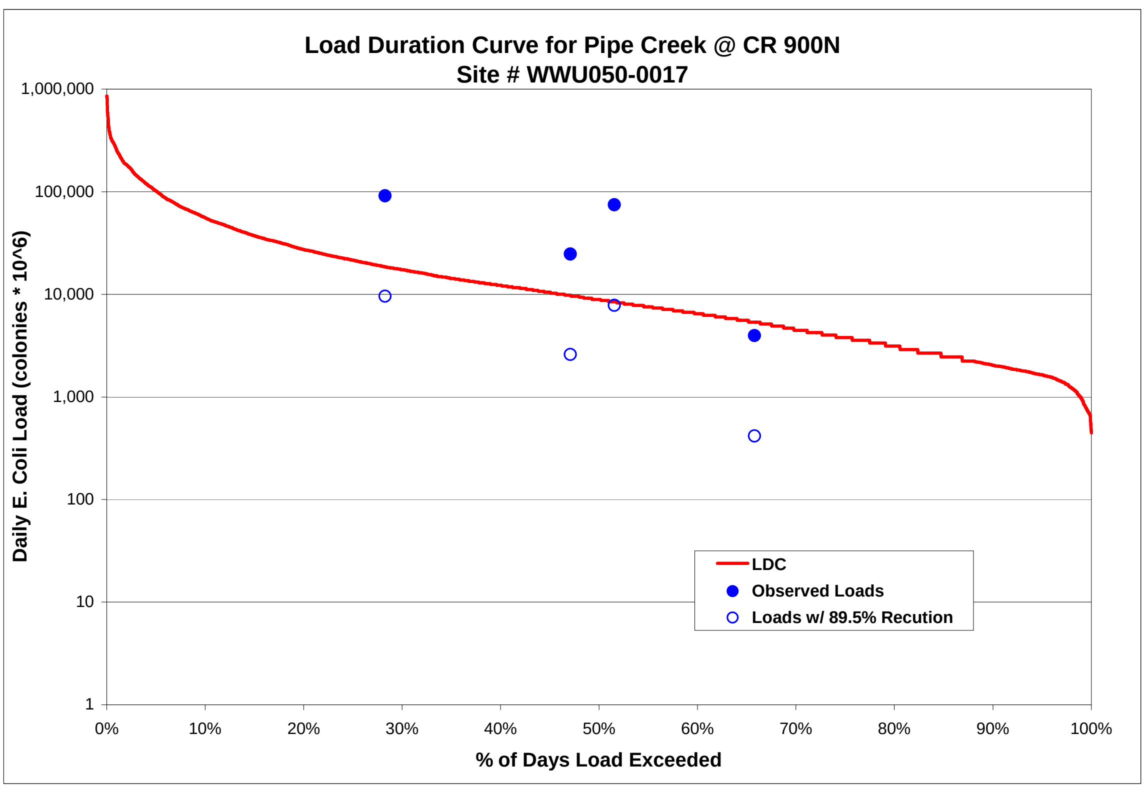

Load Duration Curve for Lamberson Ditch @ Henry Gunn Road
Site # WWU060-0021
10,000,000
1,000,000
100,000
10,000
1,000
100
10
1
Daily E. Coli Load (colonies * 10^6)
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
% of Days Load Exceeded
LDC
Observed Loads
Loads w/ 96.2% Reduction

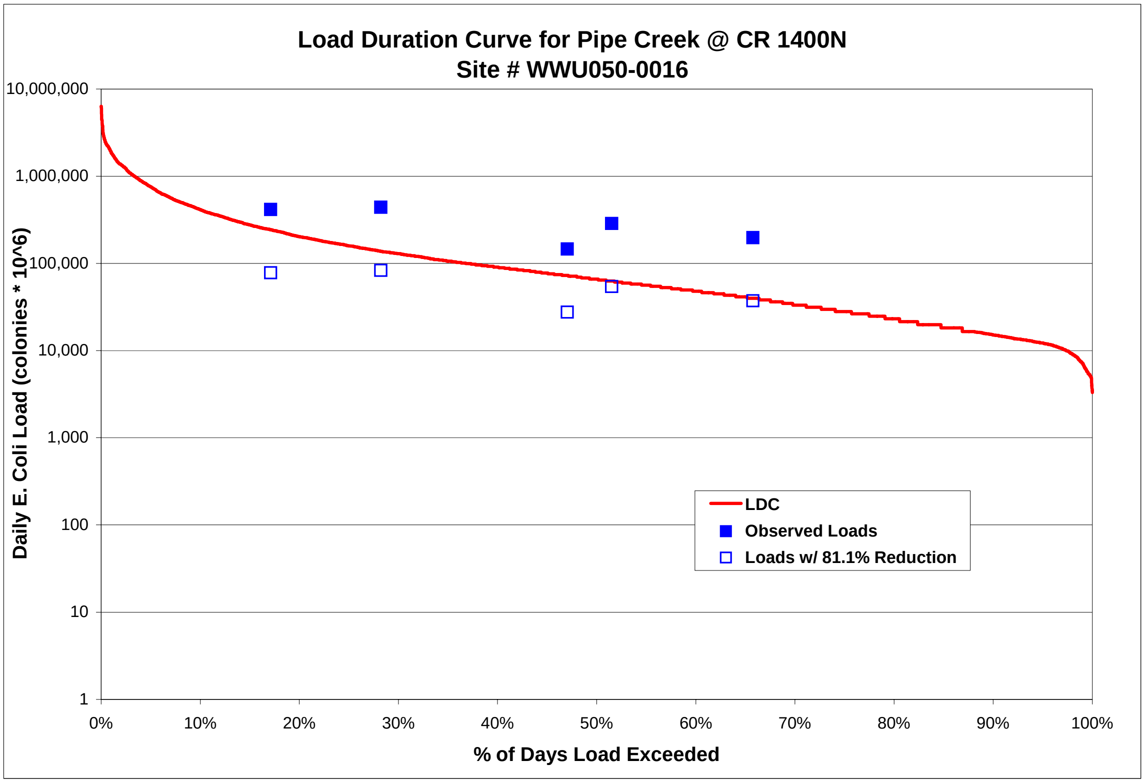


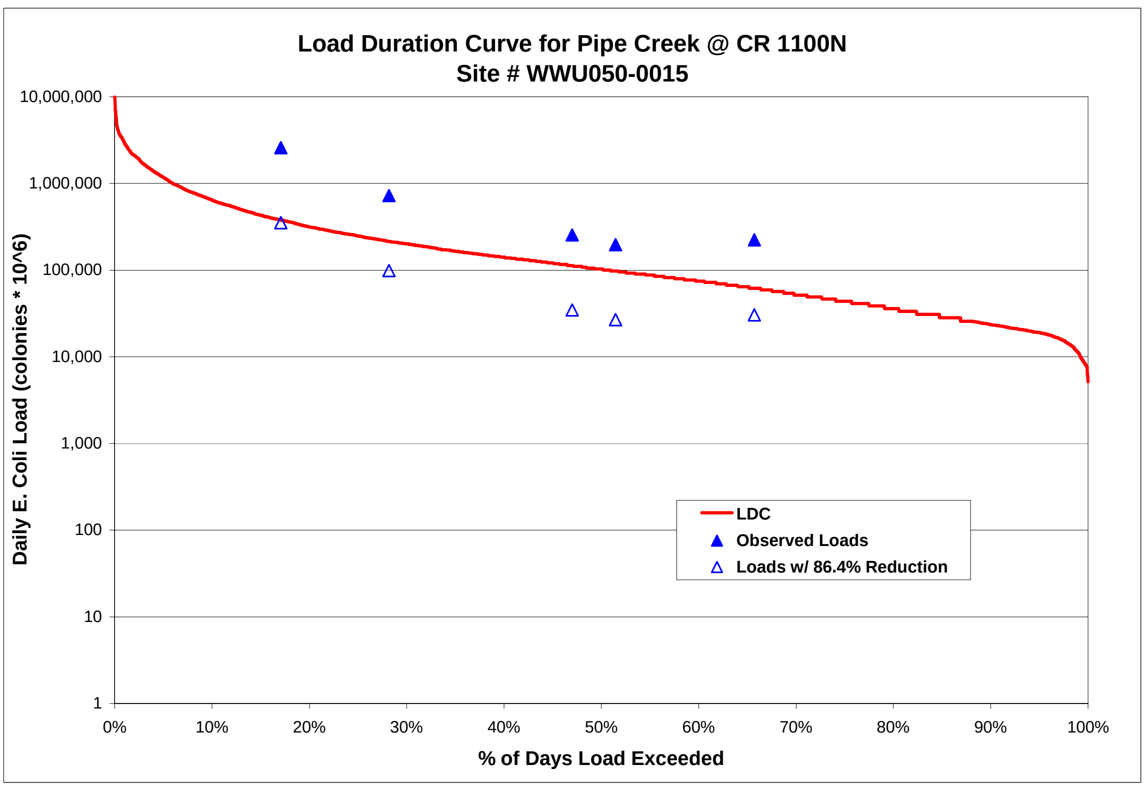
Load Duration Curve for Duck Creek @ SR 213
Site # WWU060-0003
100,000,000
10,000,000
1,000,000
100,000
10,000
1,000
100
10
1
Daily E. Coli Load (colonies * 10^6)
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
% of Days Load Exceeded
LDC
Observed Loads
Loads w/ 83.7% Reduction

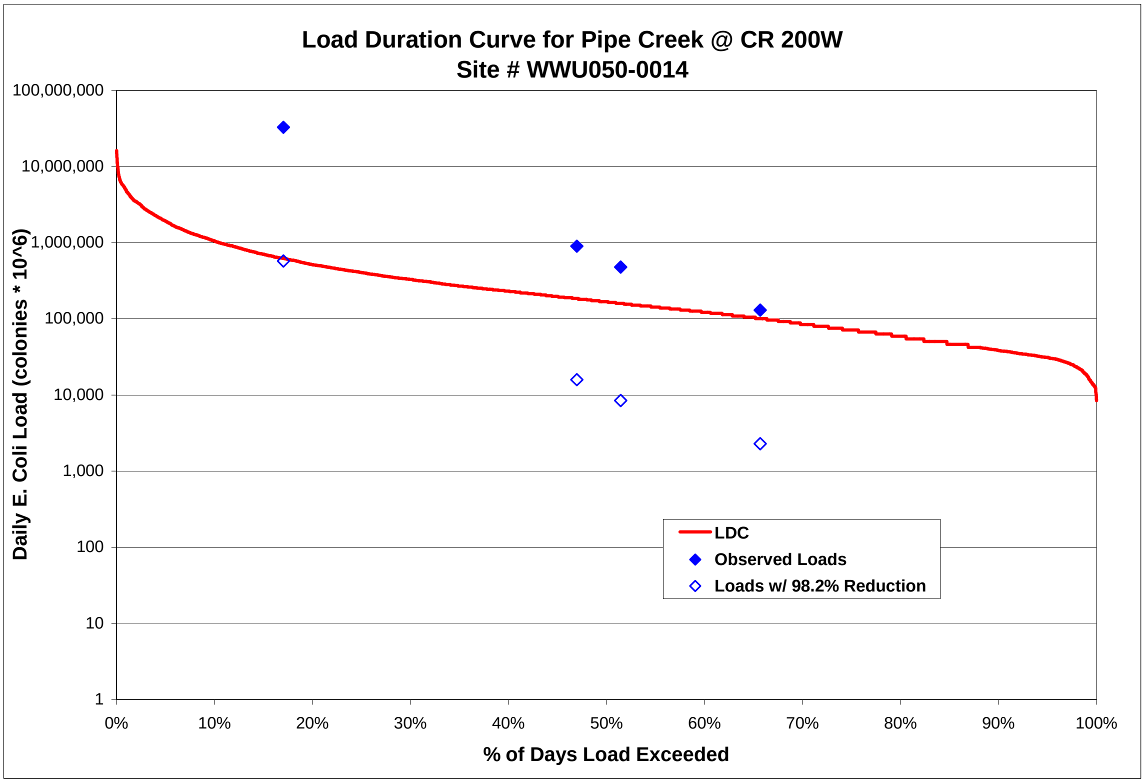
Load Duration Curves for Pipe Creek Watershed

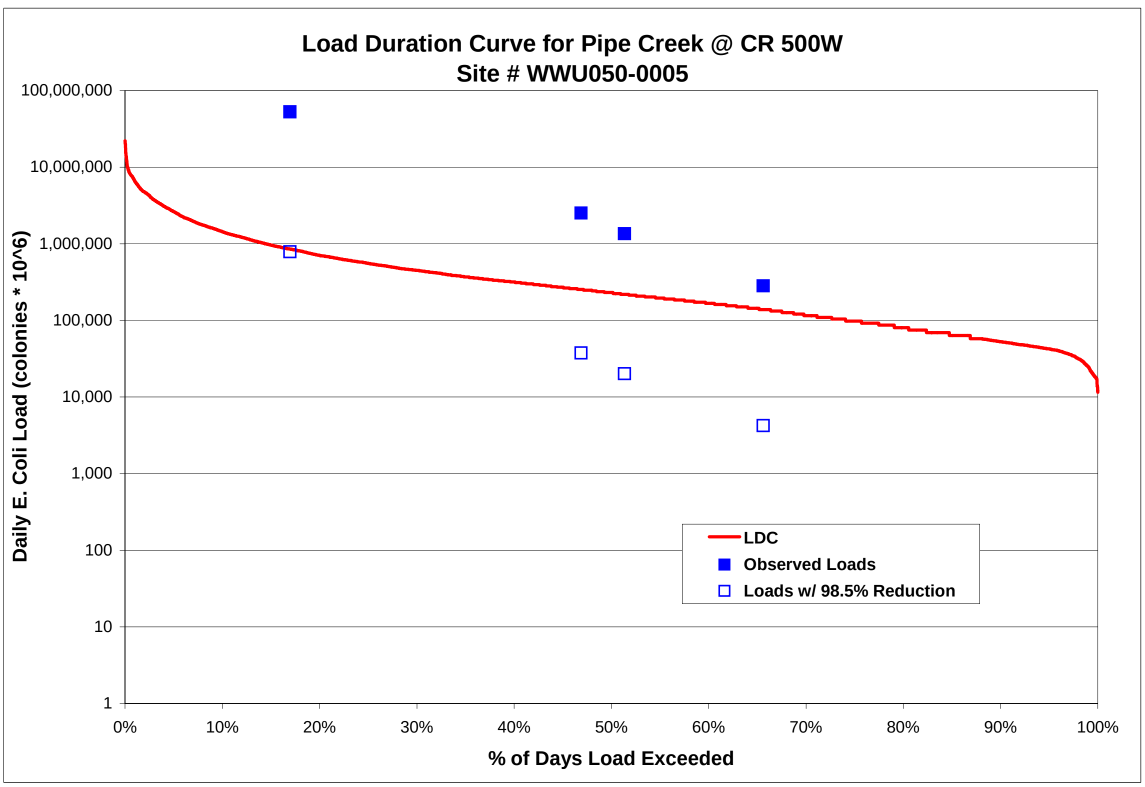


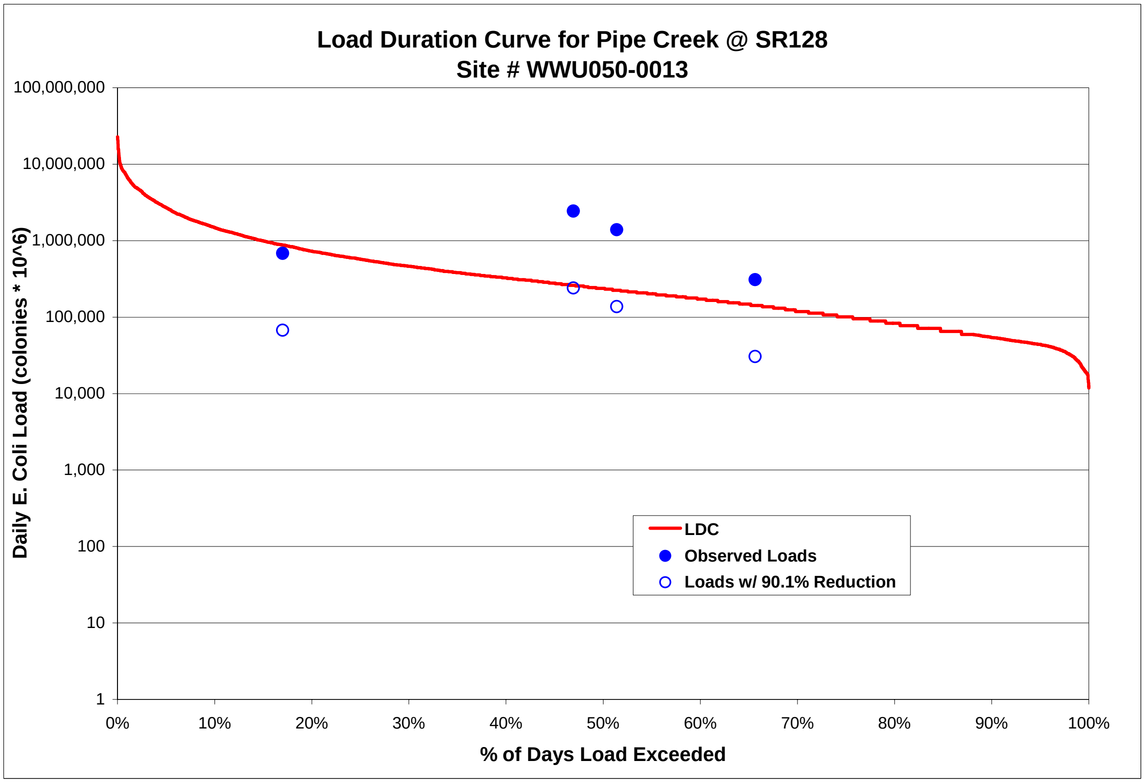


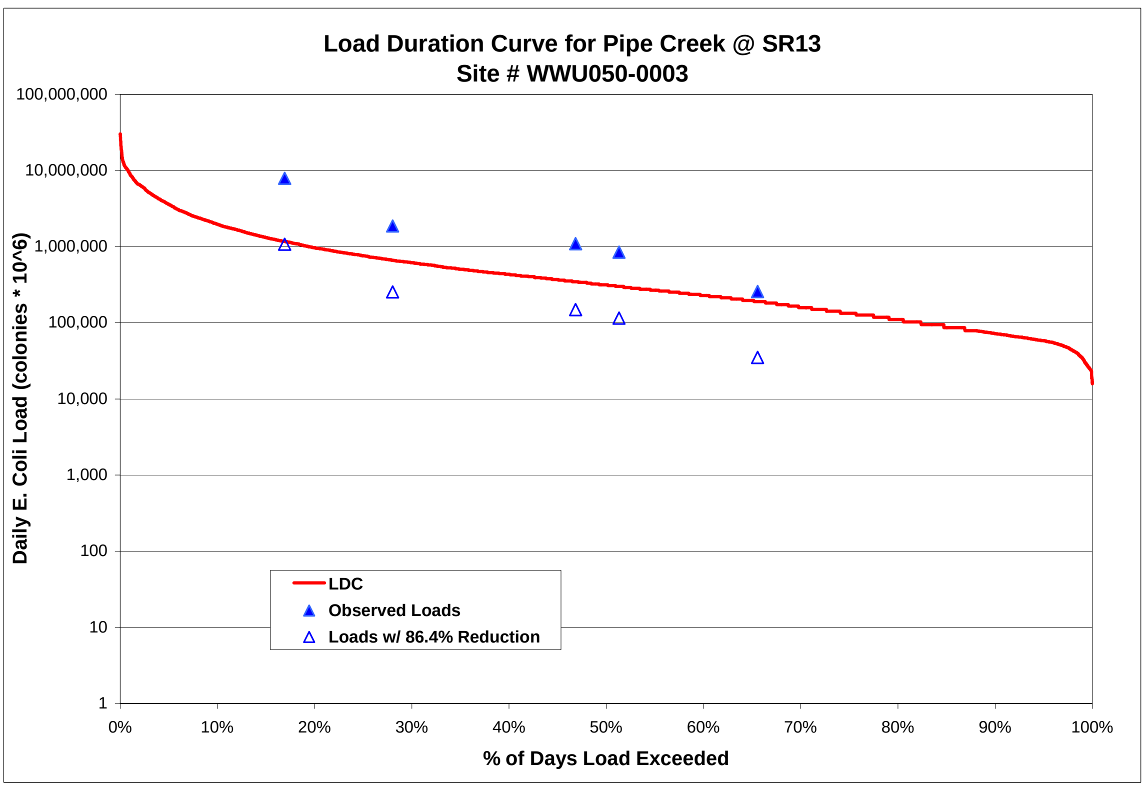

Load Duration Curve for Pipe Creek @ CR 1400N
Site # WWU050-0016
Daily E. Coli Load (colonies * 10^6)
10,000,000
1,000,000
100,000
10,000
1,000
100
10
1
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
% of Days Load Exceeded
LDC
Observed Loads
Loads w/ 81.1% Reduction


Load Duration Curve for Pipe Creek @ CR 1100N
Site # WWU050-0015
Daily E. Coli Load (colonies * 10^6)
10,000,000
1,000,000
100,000
10,000
1,000
100
10
1
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
% of Days Load Exceeded
LDC
Observed Loads
Loads w/ 86.4% Reduction

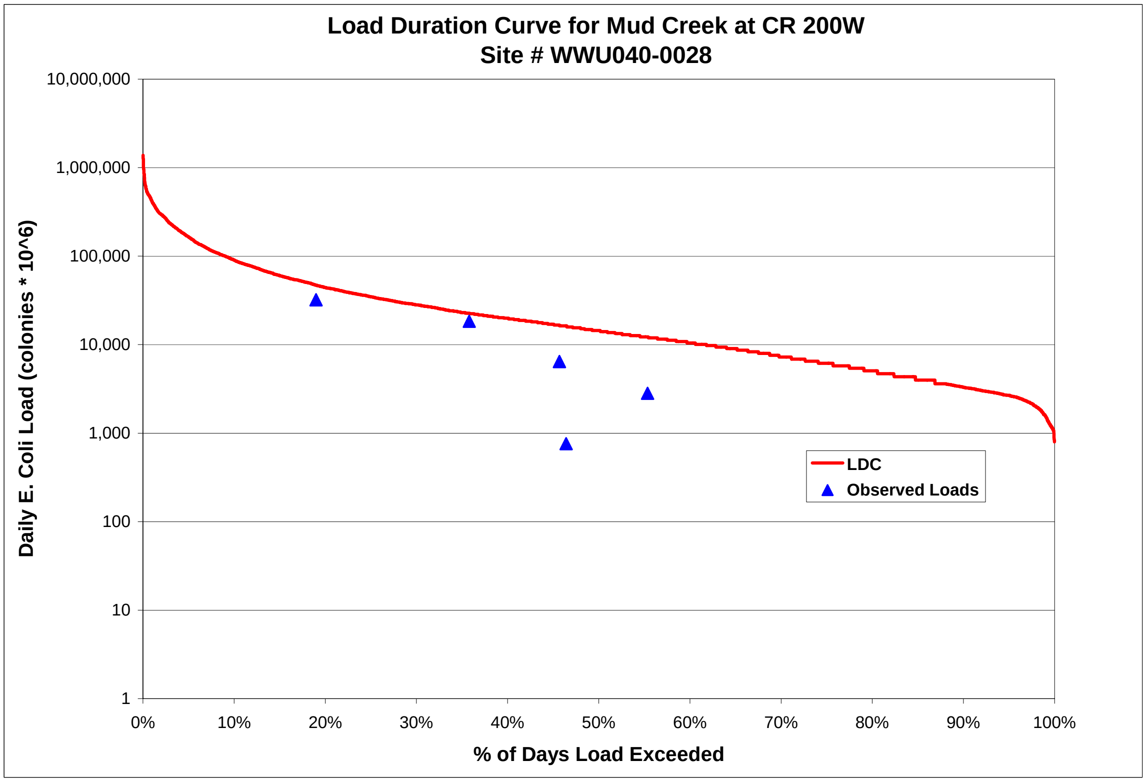

Load Duration Curve for Pipe Creek @ CR 200W
Site # WWU050-0014
Daily E. Coli Load (colonies * 10^6)
100,000,000
10,000,000
1,000,000
100,000
10,000
1,000
100
10
1
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
% of Days Load Exceeded
LDC
Observed Loads
Loads w/ 98.2% Reduction

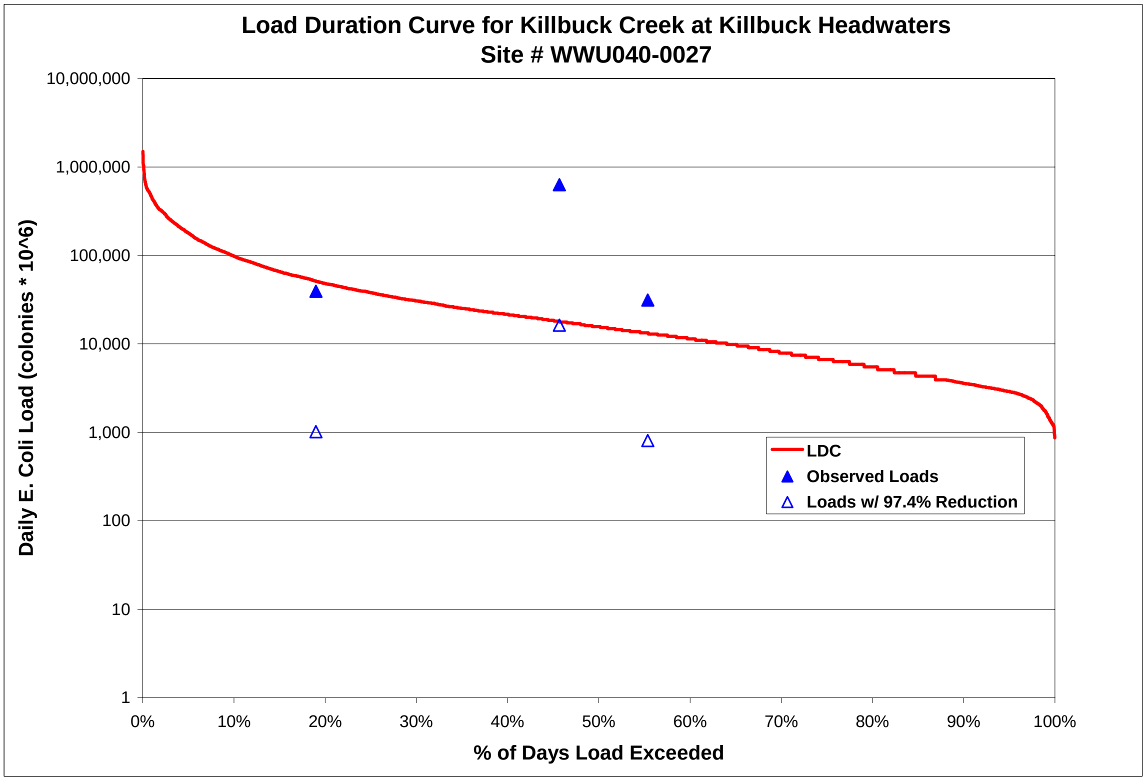

Load Duration Curve for Pipe Creek @ CR 500W
Site # WWU050-0005
Daily E. Coli Load (colonies * 10^6)
100,000,000
10,000,000
1,000,000
100,000
10,000
1,000
100
10
1
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
% of Days Load Exceeded
LDC
Observed Loads
Loads w/ 98.5% Reduction

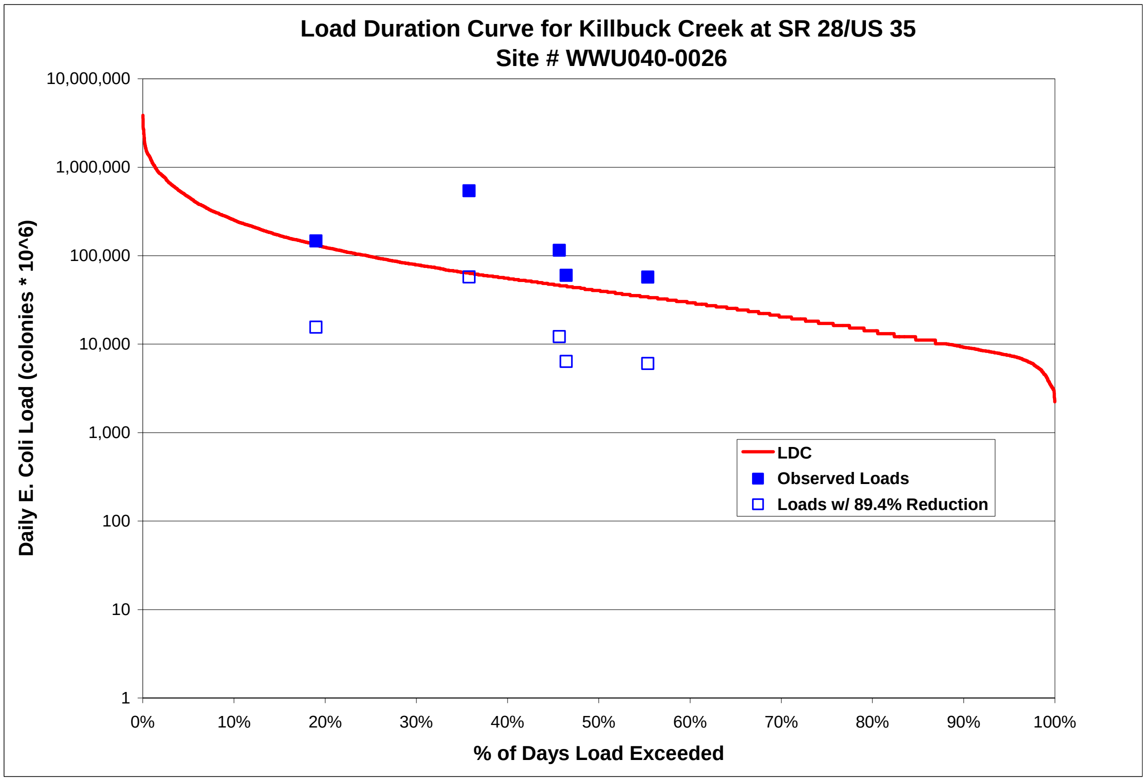

Load Duration Curve for Pipe Creek @ SR128
Site # WWU050-0013
Daily E. Coli Load (colonies * 10^6)
100,000,000
10,000,000
1,000,000
100,000
10,000
1,000
100
10
1
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
% of Days Load Exceeded
LDC
Observed Loads
Loads w/ 90.1% Reduction


Load Duration Curve for Pipe Creek @ SR13
Site # WWU050-0003
Daily E. Coli Load (colonies * 10^6)
100,000,000
10,000,000
1,000,000
100,000
10,000
1,000
100
10
1
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
% of Days Load Exceeded
LDC
Observed Loads
Loads w/ 86.4% Reduction

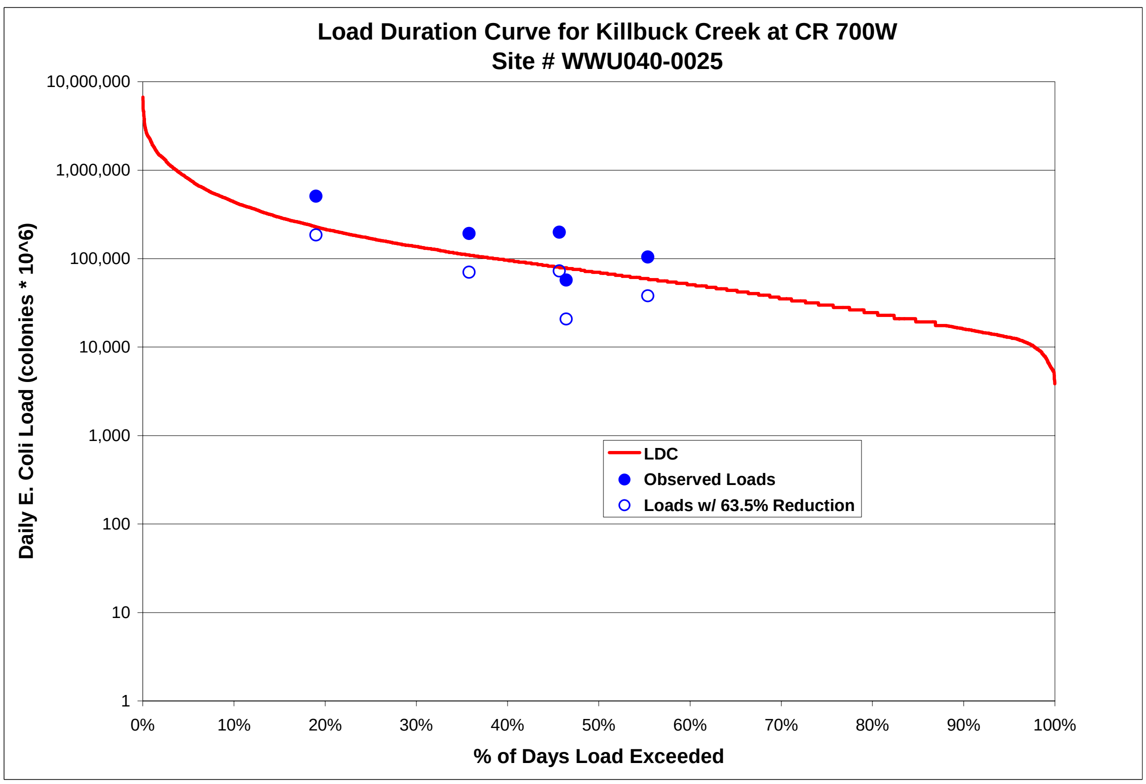
Load Duration Curves for Killbuck Creek Watershed



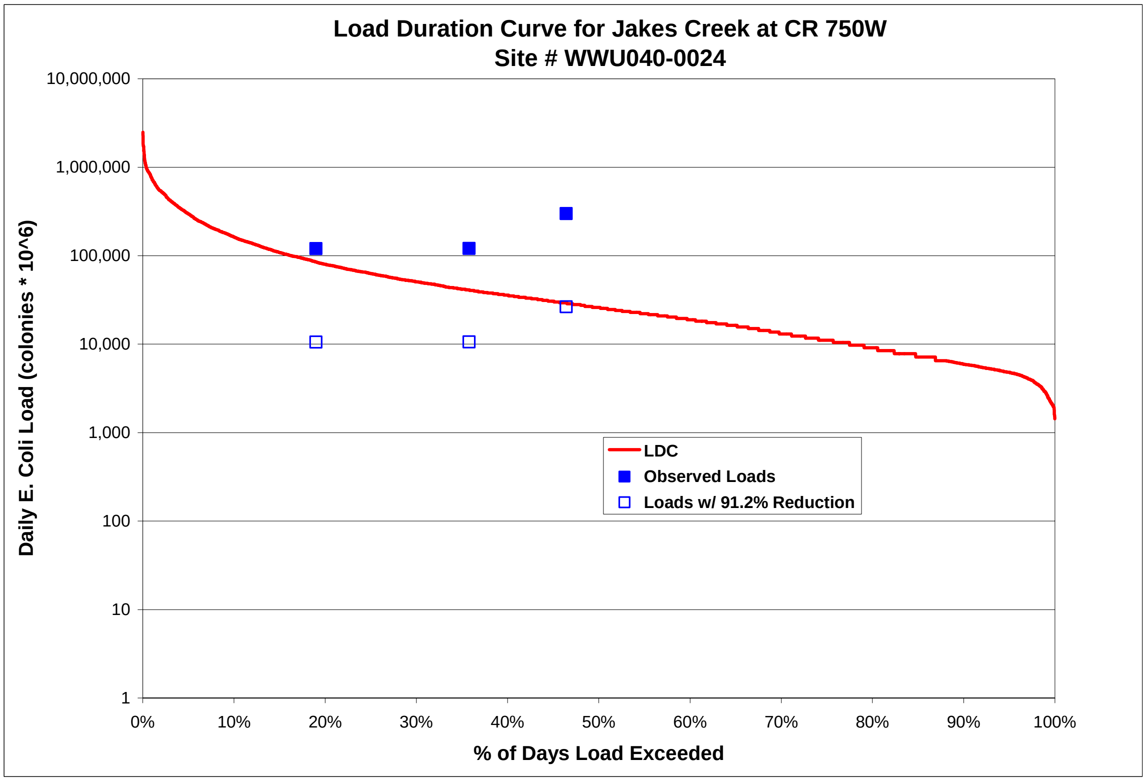


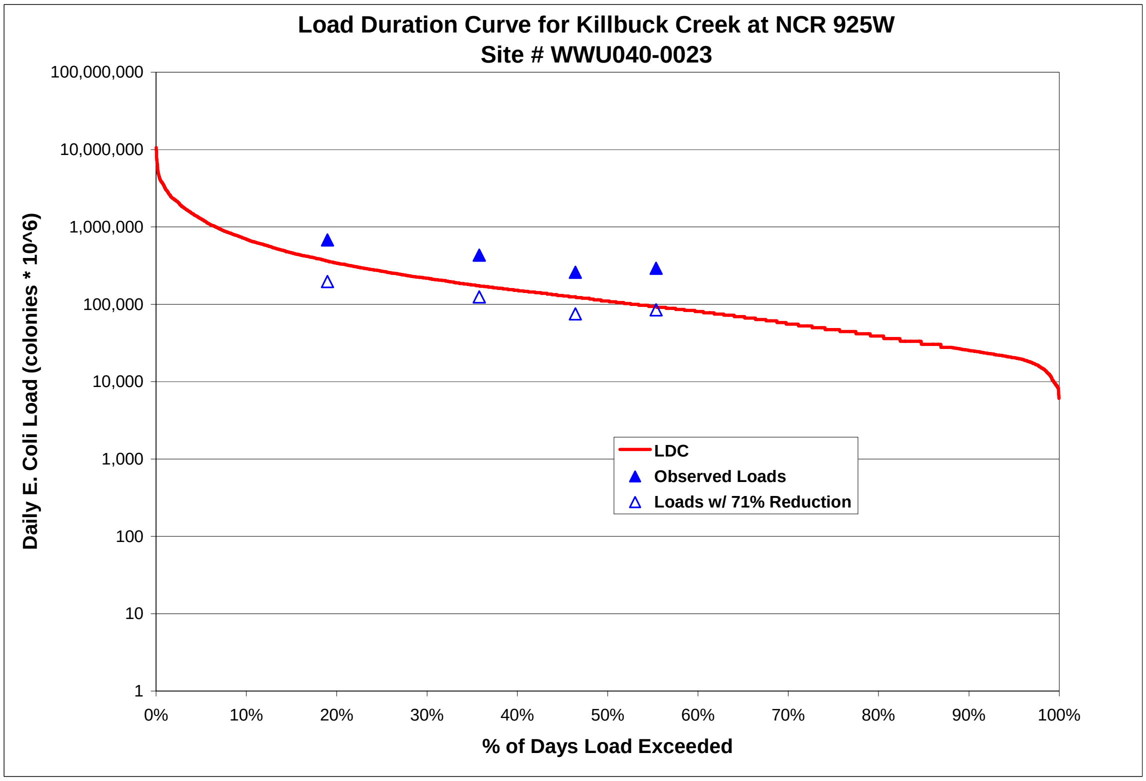


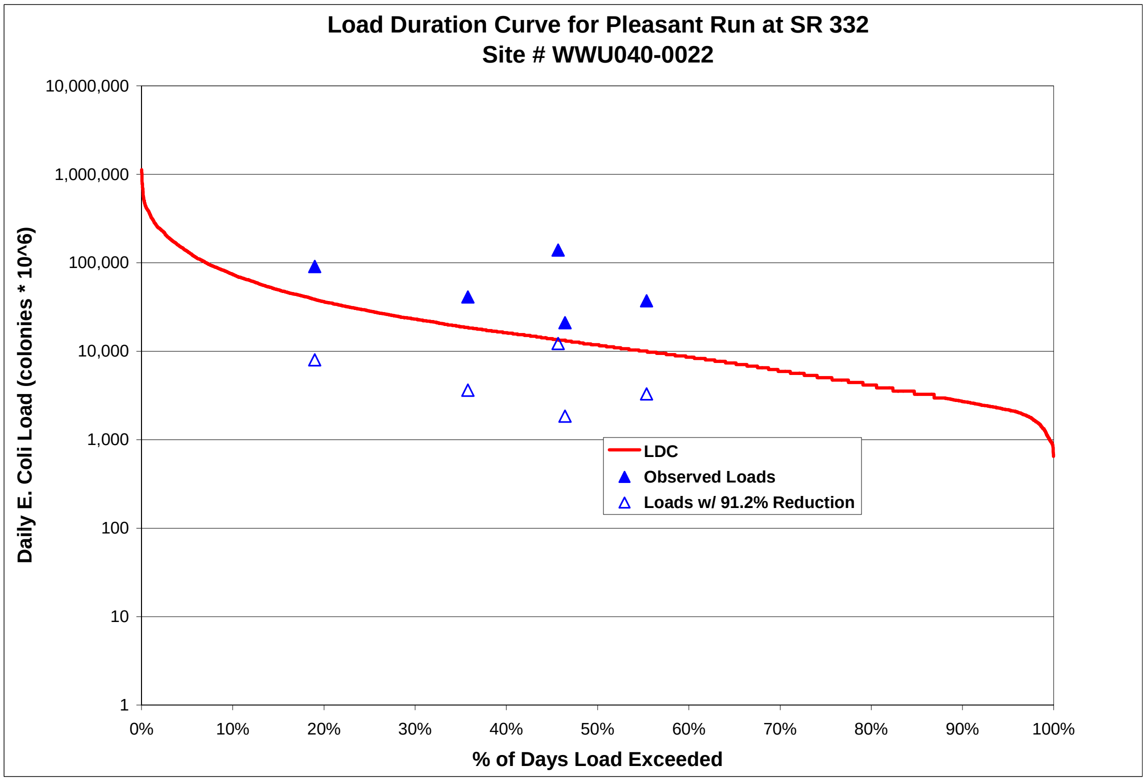
Load Duration Curve for Killbuck Creek at SR 28/US 35
Site # WWU040-0026
Daily E. Coli Load (colonies * 10^6)
10,000,000
1,000,000
100,000
10,000
1,000
100
10
1
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
% of Days Load Exceeded
LDC
Observed Loads
Loads w/ 89.4% Reduction

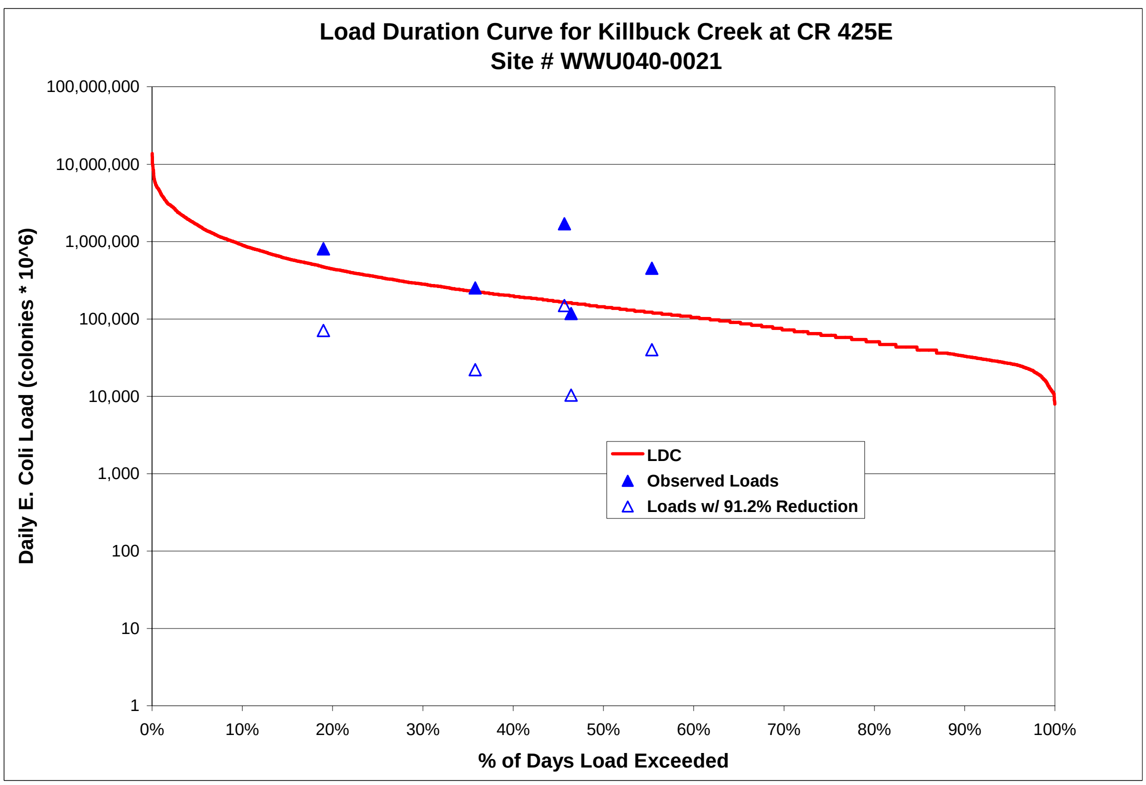


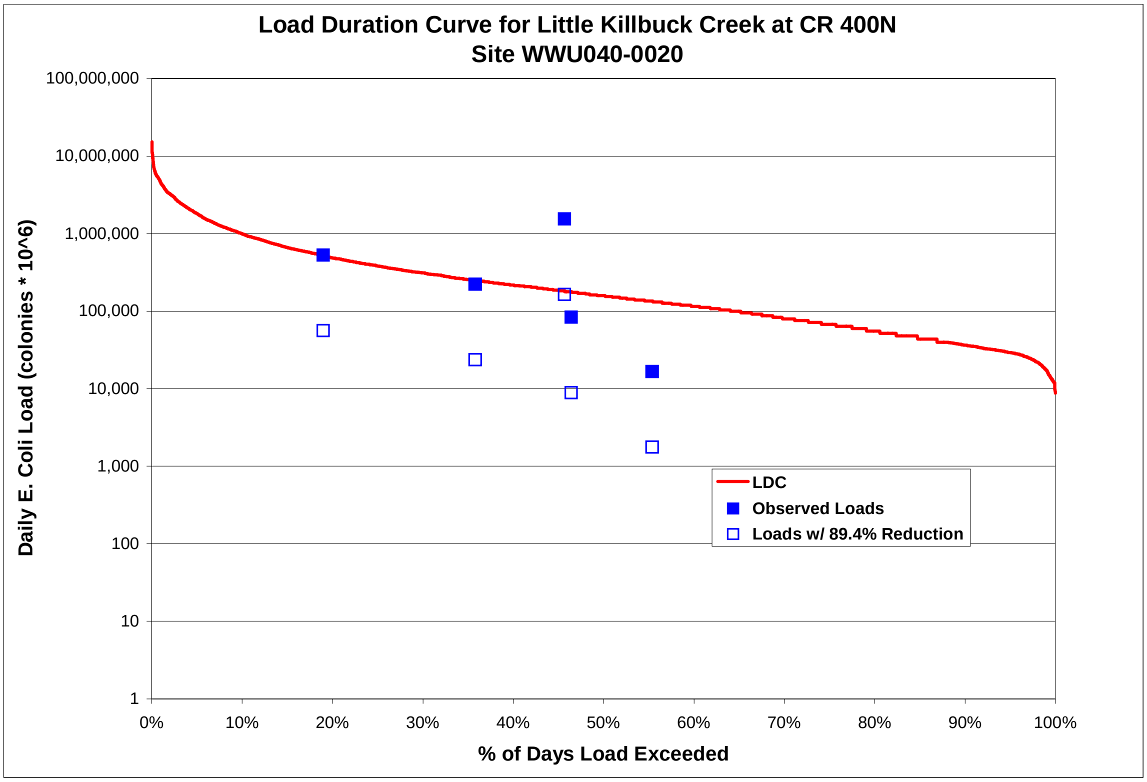
Load Duration Curve for Killbuck Creek at CR 700W
Site # WWU040-0025
Daily E. Coli Load (colonies * 10^6)
10,000,000
1,000,000
100,000
10,000
1,000
100
10
1
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
% of Days Load Exceeded
LDC
Observed Loads
Loads w/ 63.5% Reduction

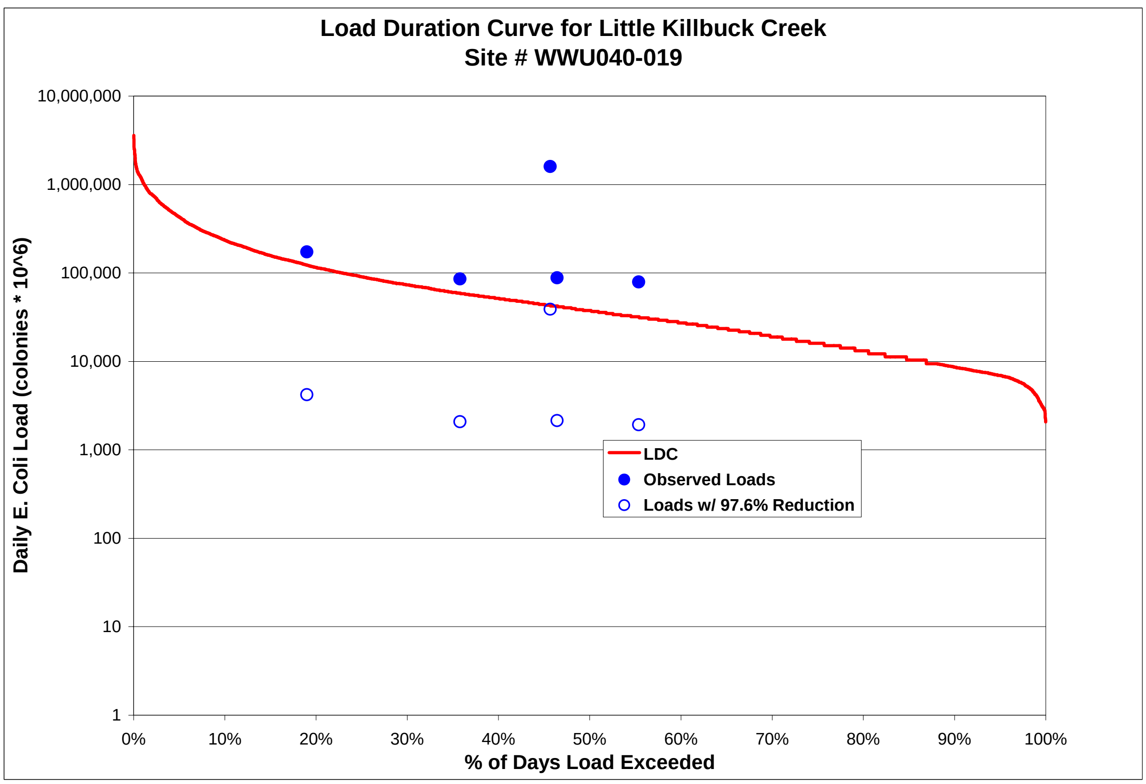

Load Duration Curve for Jakes Creek at CR 750W
Site # WWU040-0024
Daily E. Coli Load (colonies * 10^6)
10,000,000
1,000,000
100,000
10,000
1,000
100
10
1
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
% of Days Load Exceeded
LDC
Observed Loads
Loads w/ 91.2% Reduction

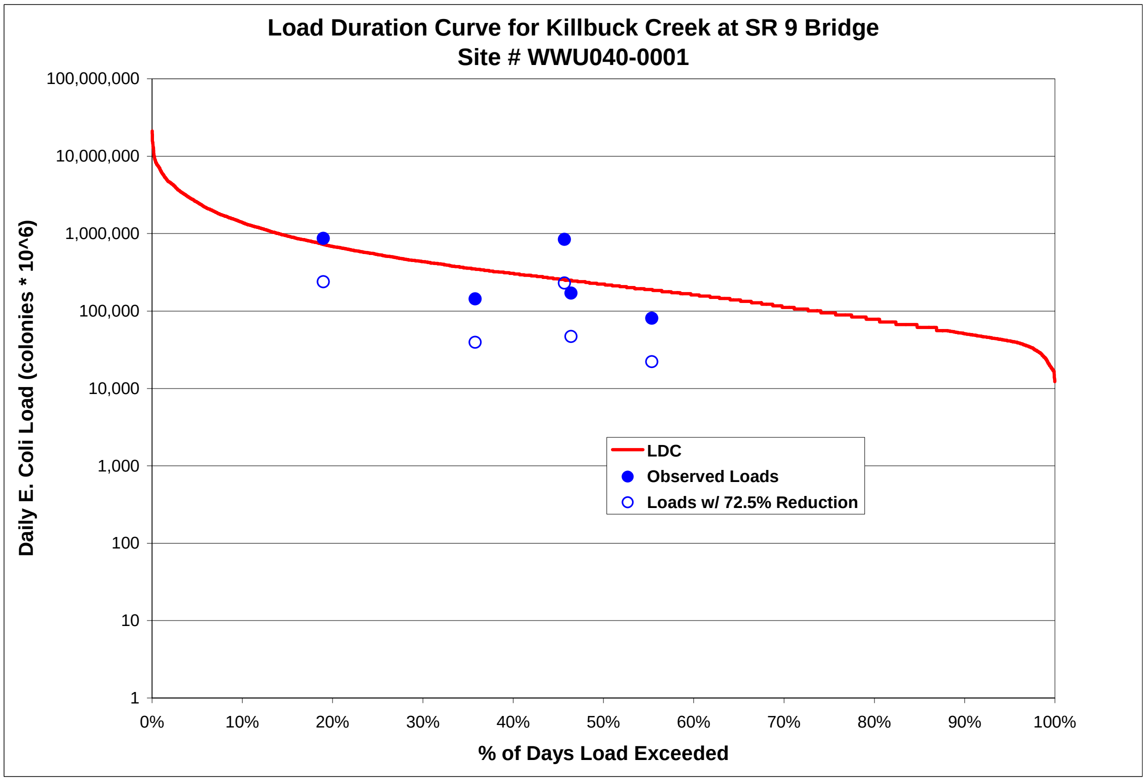

Load Duration Curve for Killbuck Creek at NCR 925W
Site # WWU040-0023
Daily E. Coli Load (colonies * 10^6)
100,000,000
10,000,000
1,000,000
100,000
10,000
1,000
100
10
1
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
% of Days Load Exceeded
LDC
Observed Loads
Loads w/ 71% Reduction

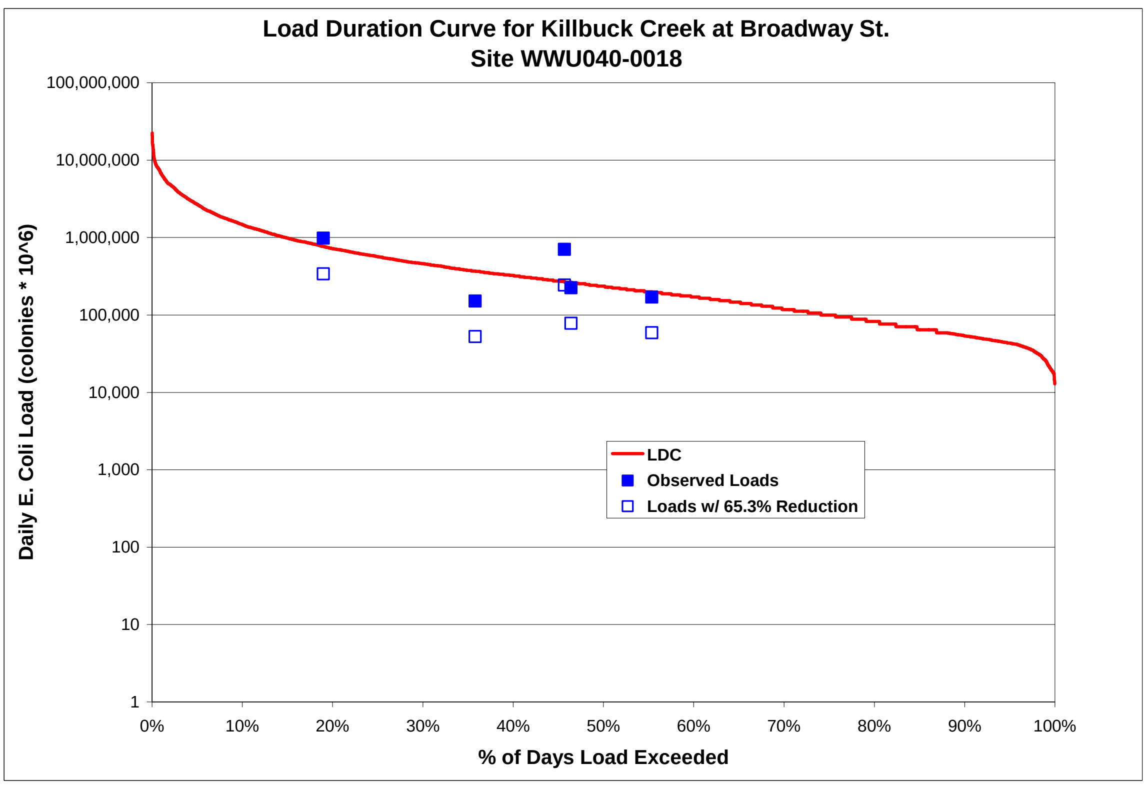

Load Duration Curve for Pleasant Run at SR 332
Site # WWU040-0022
Daily E. Coli Load (colonies * 10^6)
10,000,000
1,000,000
100,000
10,000
1,000
100
10
1
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
% of Days Load Exceeded
LDC
Observed Loads
Loads w/ 91.2% Reduction


Load Duration Curve for Killbuck Creek at CR 425E
Site # WWU040-0021
Daily E. Coli Load (colonies * 10^6)
100,000,000
10,000,000
1,000,000
100,000
10,000
1,000
100
10
1
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
% of Days Load Exceeded
LDC
Observed Loads
Loads w/ 91.2% Reduction

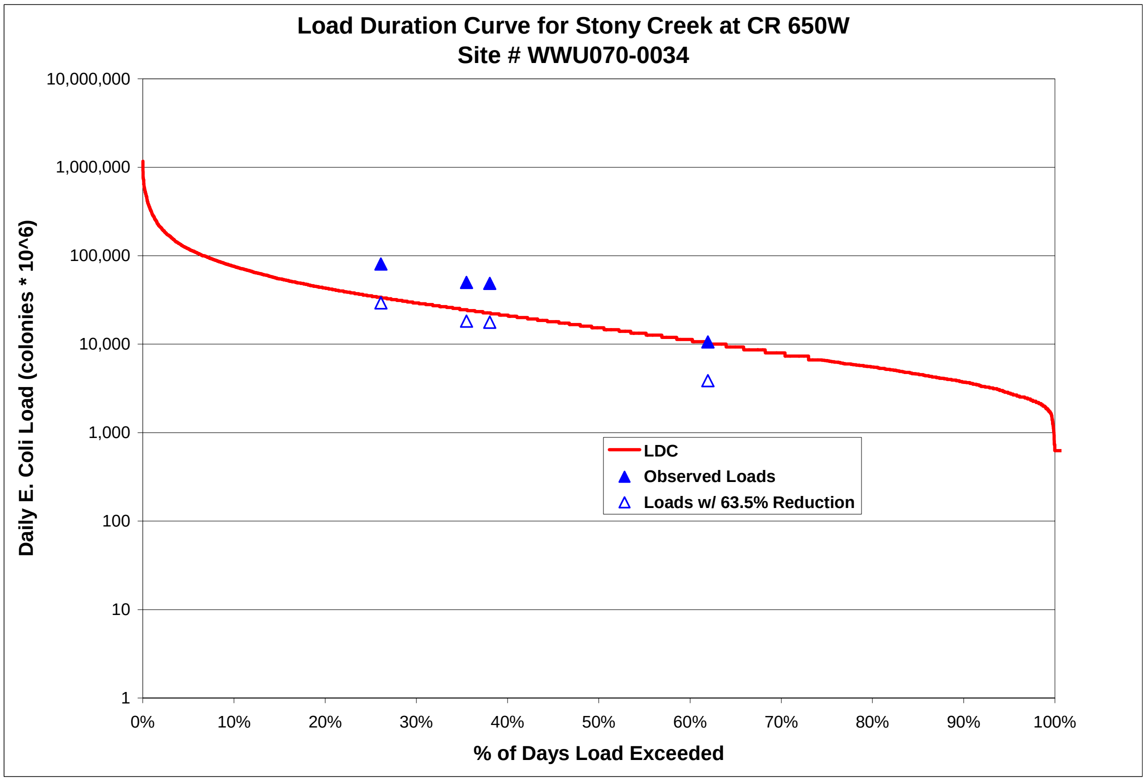

Load Duration Curve for Little Killbuck Creek at CR 400N
Site WWU040-0020
100,000,000
10,000,000
1,000,000
100,000
10,000
1,000
100
10
1
Daily E. Coli Load (colonies * 10^6)
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
% of Days Load Exceeded
LDC
Observed Loads
Loads w/ 89.4% Reduction

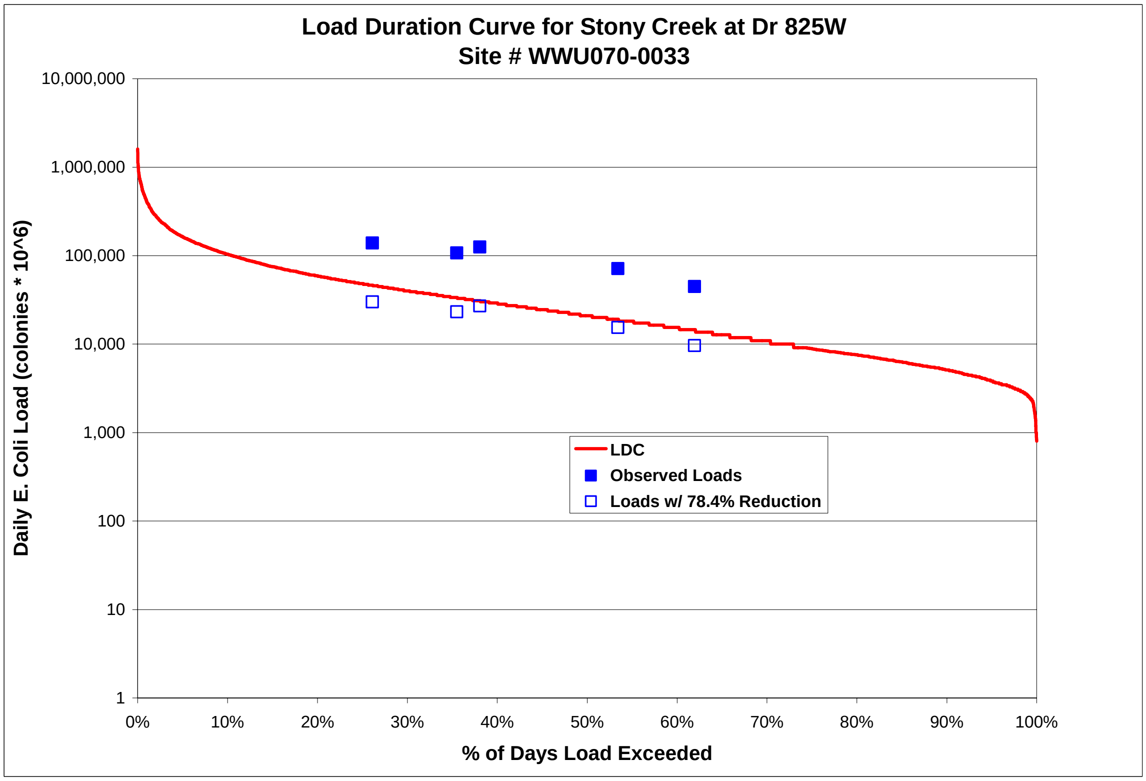

Load Duration Curve for Little Killbuck Creek
Site # WWU040-019
10,000,000
1,000,000
100,000
10,000
1,000
100
10
1
Daily E. Coli Load (colonies * 10^6)
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
% of Days Load Exceeded
LDC
Observed Loads
Loads w/ 97.6% Reduction

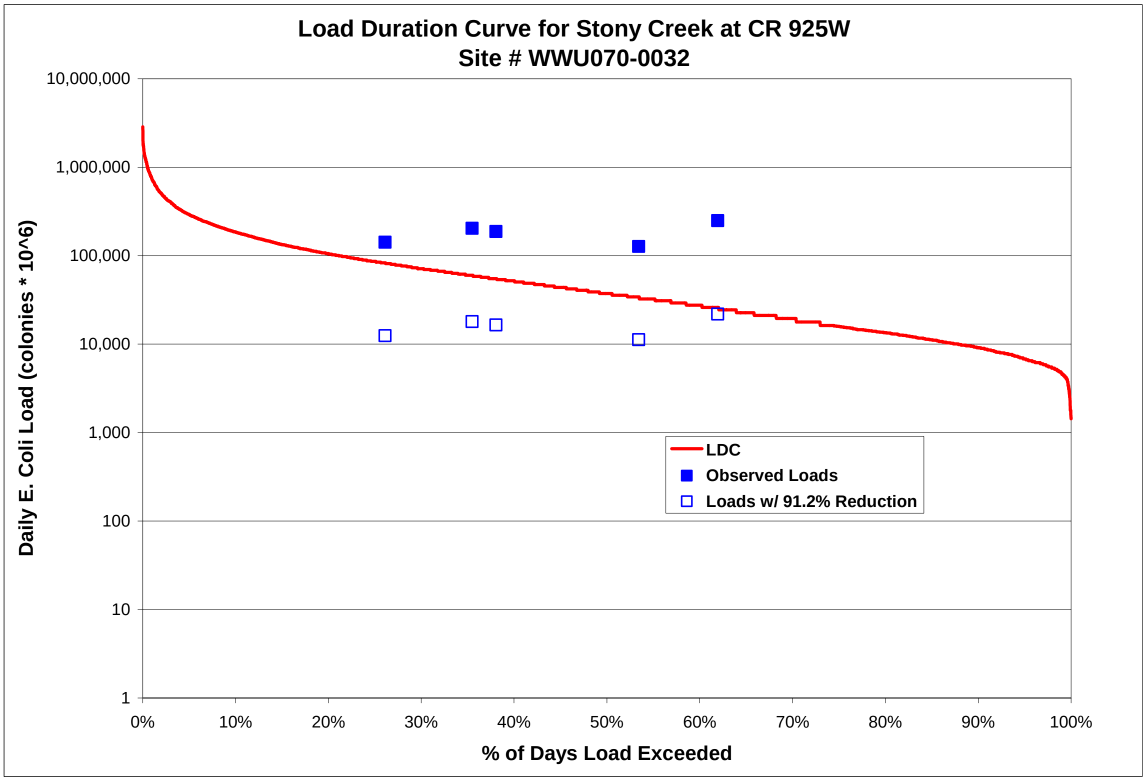

Load Duration Curve for Killbuck Creek at SR 9 Bridge
Site # WWU040-0001
Daily E. Coli Load (colonies * 10^6)
100,000,000
10,000,000
1,000,000
100,000
10,000
1,000
100
10
1
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
% of Days Load Exceeded
LDC
Observed Loads
Loads w/ 72.5% Reduction

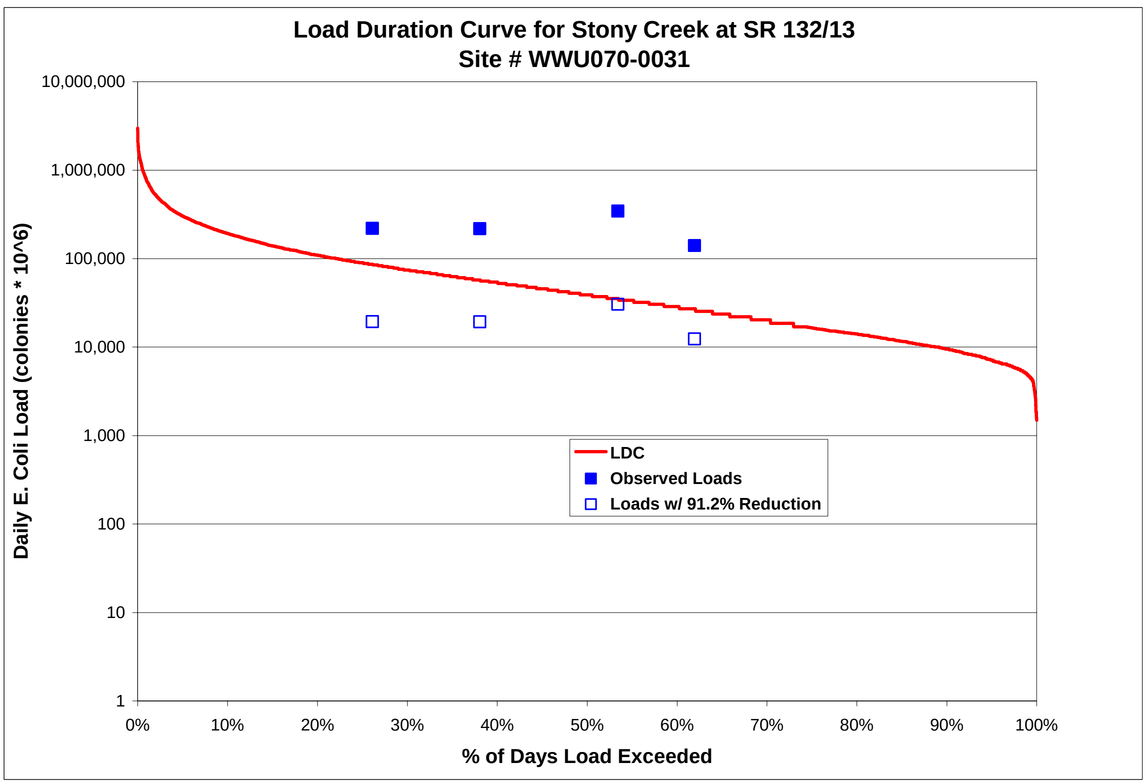

Load Duration Curve for Killbuck Creek at Broadway St.
Site WWU040-0018
Daily E. Coli Load (colonies * 10^6)
100,000,000
10,000,000
1,000,000
100,000
10,000
1,000
100
10
1
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
% of Days Load Exceeded
LDC
Observed Loads
Loads w/ 65.3% Reduction

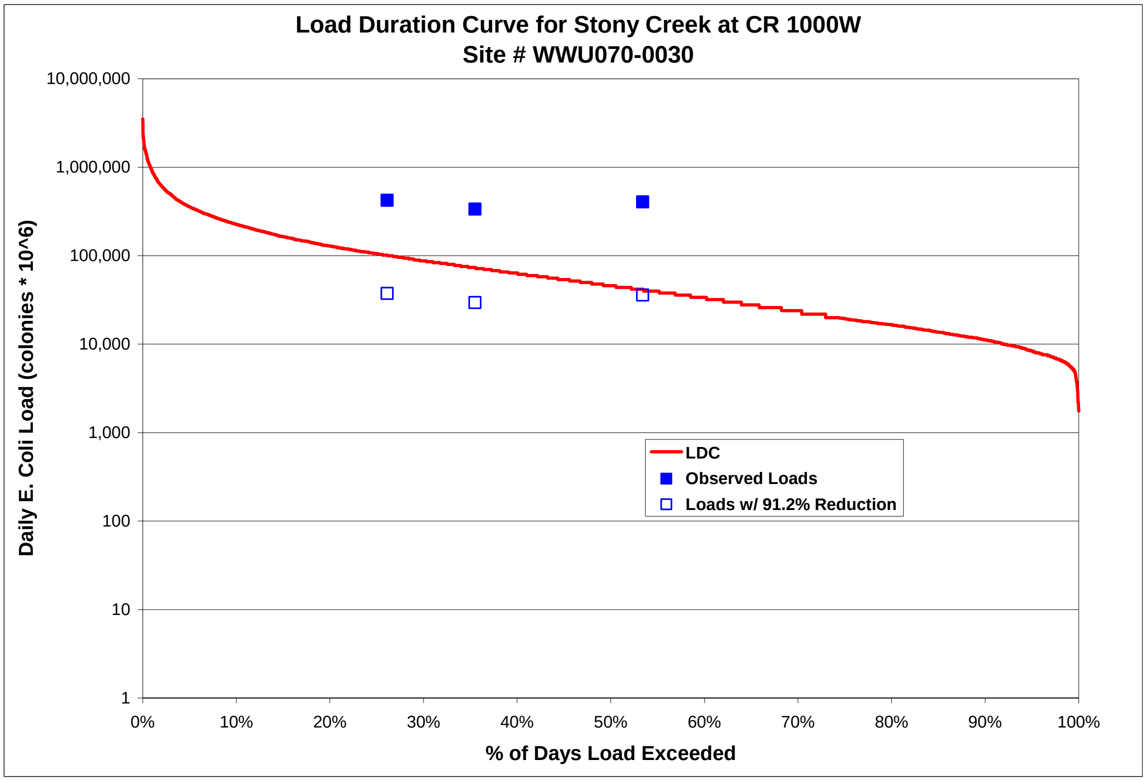
Load Duration Curves for Stony Creek Watershed

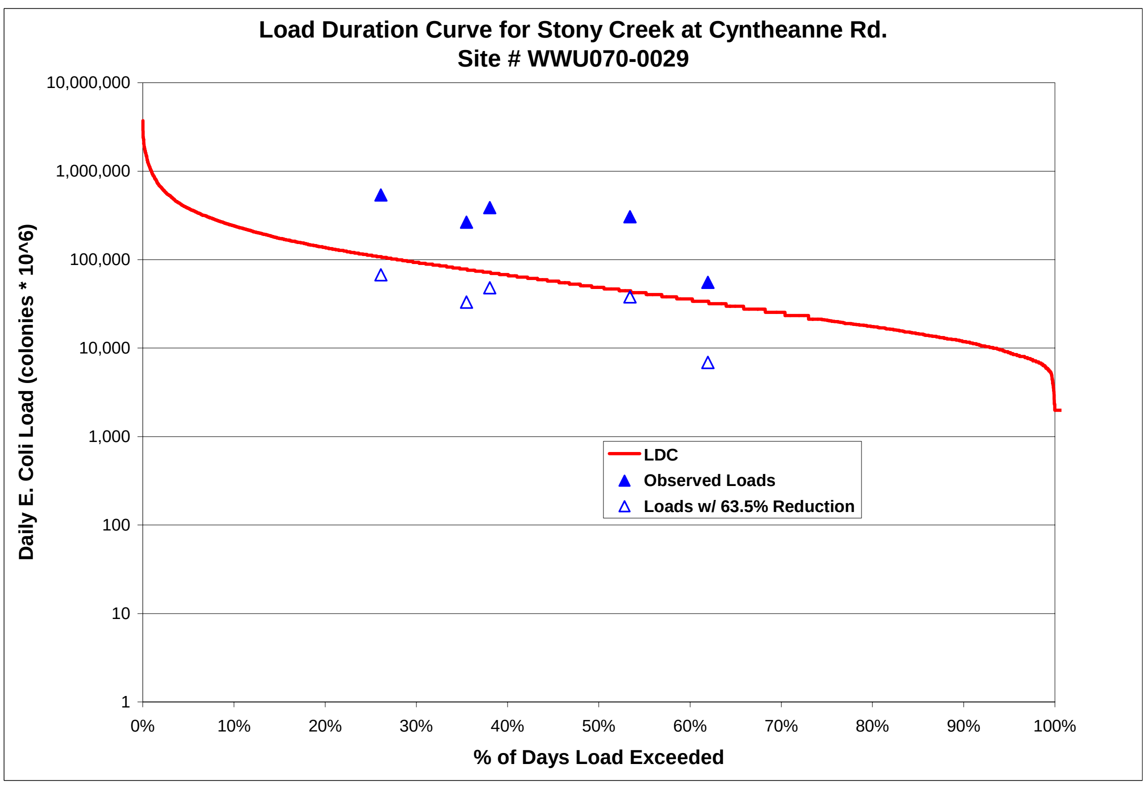


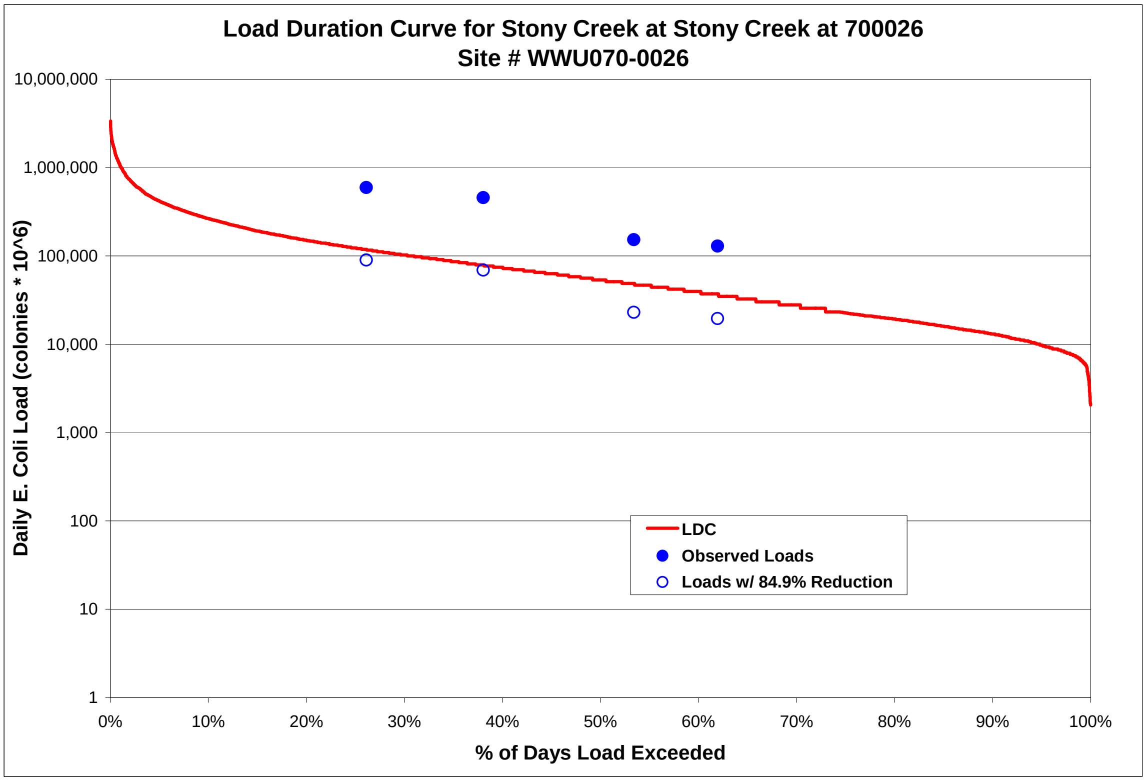


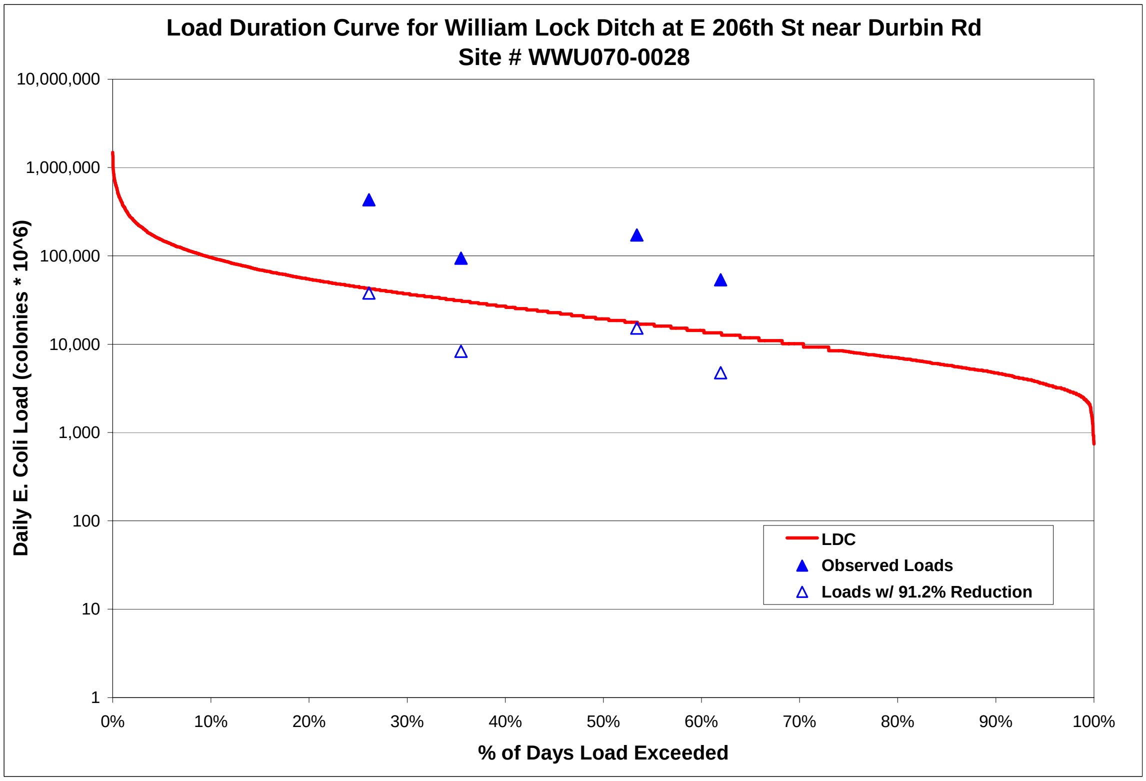

Load Duration Curve for Stony Creek at CR 925W
Site # WWU070-0032
Daily E. Coli Load (colonies * 10^6)
10,000,000
1,000,000
100,000
10,000
1,000
100
10
1
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
% of Days Load Exceeded
LDC
Observed Loads
Loads w/ 91.2% Reduction

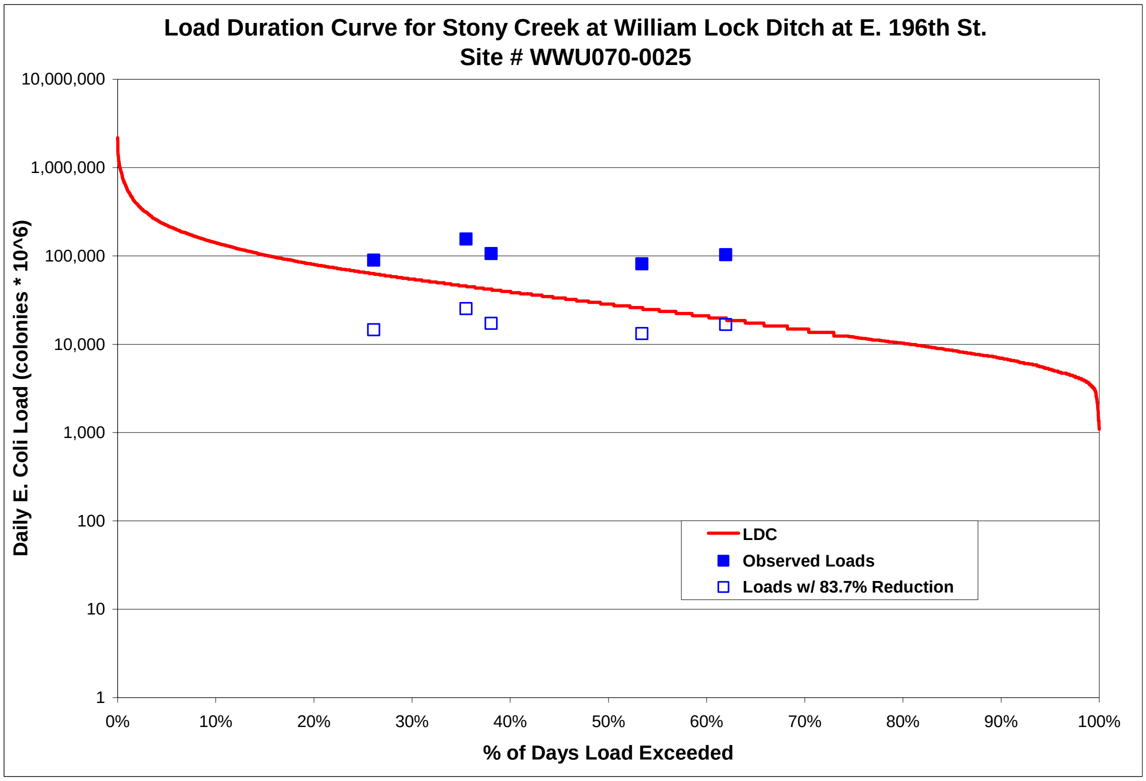

Load Duration Curve for Stony Creek at SR 132/13
Site # WWU070-0031
Daily E. Coli Load (colonies * 10^6)
10,000,000
1,000,000
100,000
10,000
1,000
100
10
1
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
% of Days Load Exceeded
LDC
Observed Loads
Loads w/ 91.2% Reduction


Load Duration Curve for Stony Creek at CR 1000W
Site # WWU070-0030
10,000,000
1,000,000
100,000
10,000
1,000
100
10
1
Daily E. Coli Load (colonies * 10^6)
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
% of Days Load Exceeded
LDC
Observed Loads
Loads w/ 91.2% Reduction

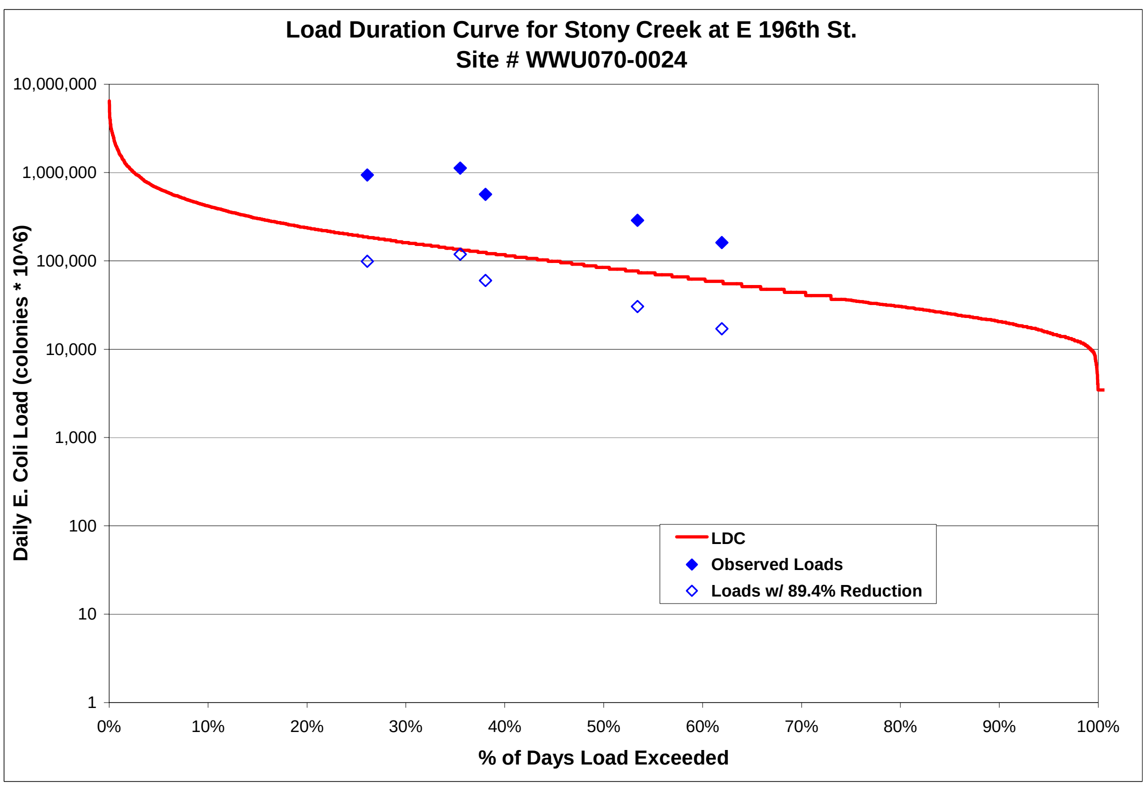

Load Duration Curve for Stony Creek at Cyntheanne Rd.
Site # WWU070-0029
10,000,000
1,000,000
100,000
10,000
1,000
100
10
1
Daily E. Coli Load (colonies * 10^6)
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
% of Days Load Exceeded
LDC
Observed Loads
Loads w/ 63.5% Reduction


Load Duration Curve for Stony Creek at Stony Creek at 700026
Site # WWU070-0026
10,000,000
1,000,000
100,000
10,000
1,000
100
10
1
Daily E. Coli Load (colonies * 10^6)
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
% of Days Load Exceeded
LDC
Observed Loads
Loads w/ 84.9% Reduction

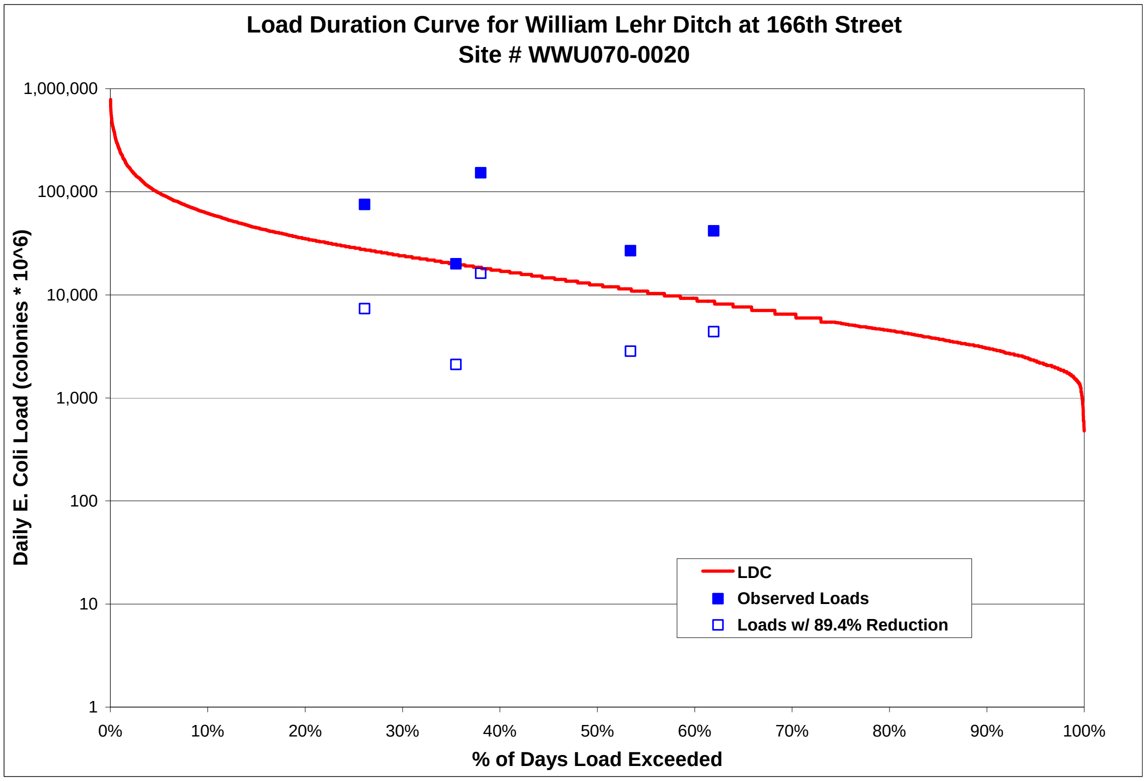

Load Duration Curve for William Lock Ditch at E 206th St near Durbin Rd
Site # WWU070-0028
10,000,000
1,000,000
100,000
10,000
1,000
100
10
1
Daily E. Coli Load (colonies * 10^6)
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
% of Days Load Exceeded
LDC
Observed Loads
Loads w/ 91.2% Reduction

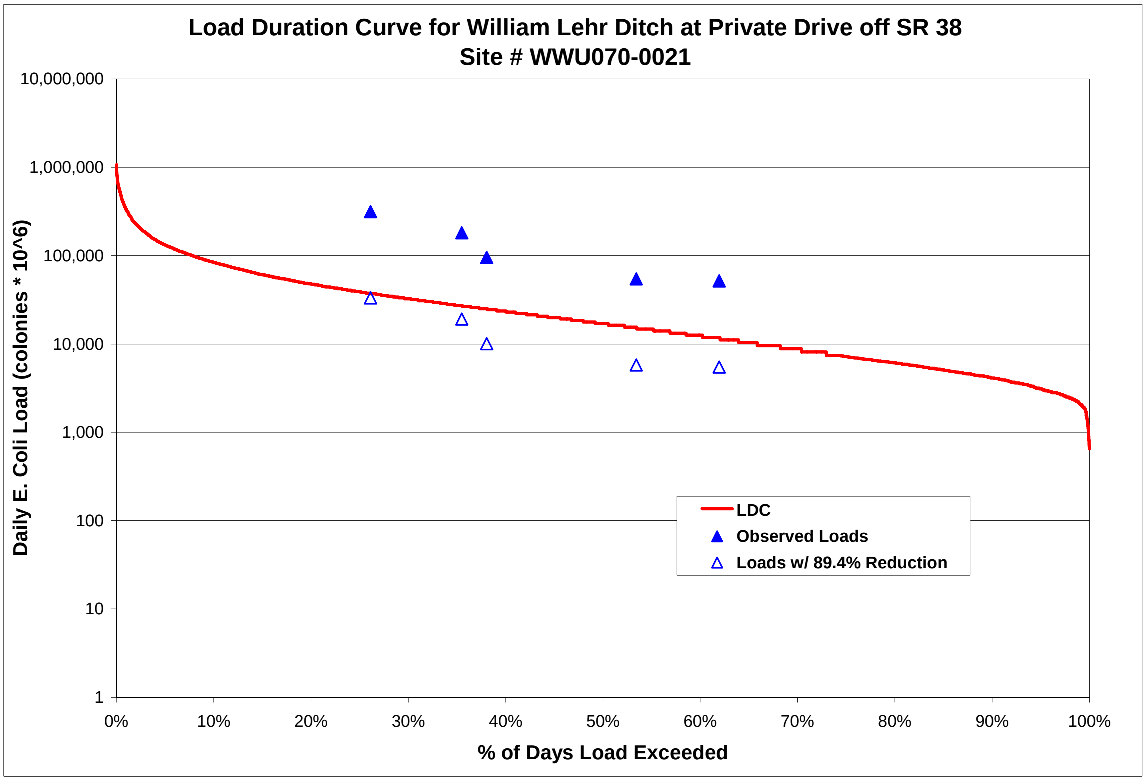


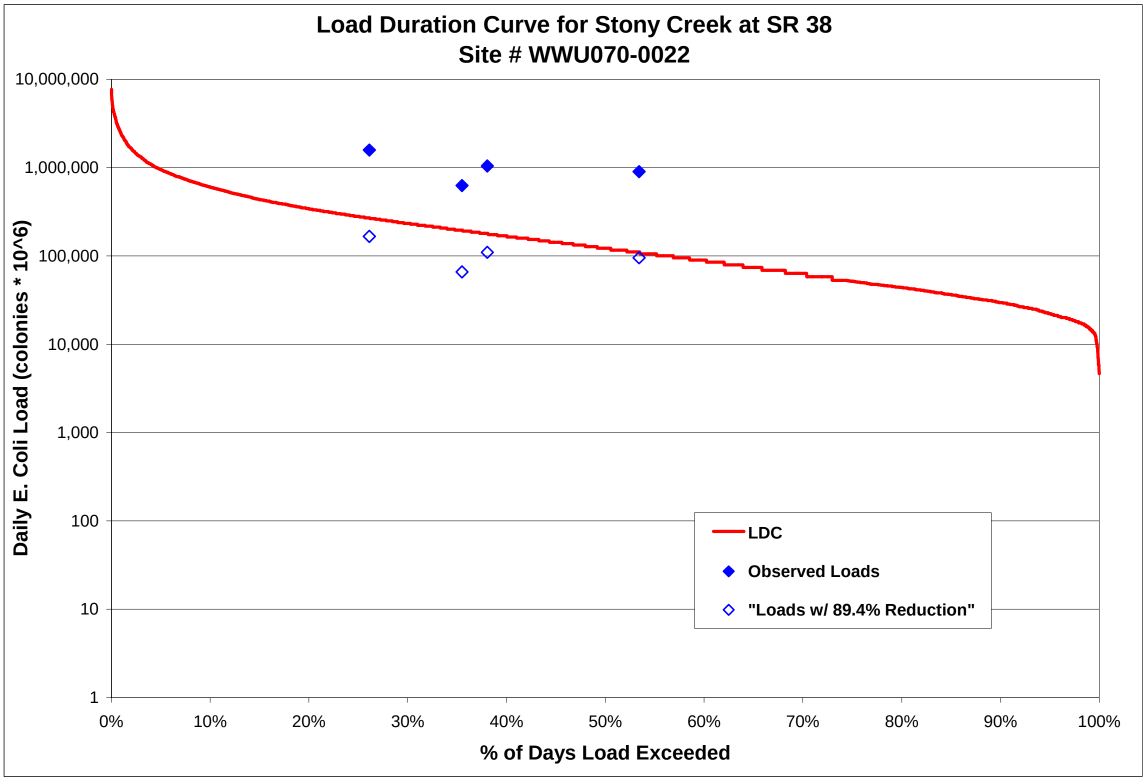
Load Duration Curve for Stony Creek at William Lock Ditch at E. 196th St.
Site # WWU070-0025
Daily E. Coli Load (colonies * 10^6)
10,000,000
1,000,000
100,000
10,000
1,000
100
10
1
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
% of Days Load Exceeded
LDC
Observed Loads
Loads w/ 83.7% Reduction



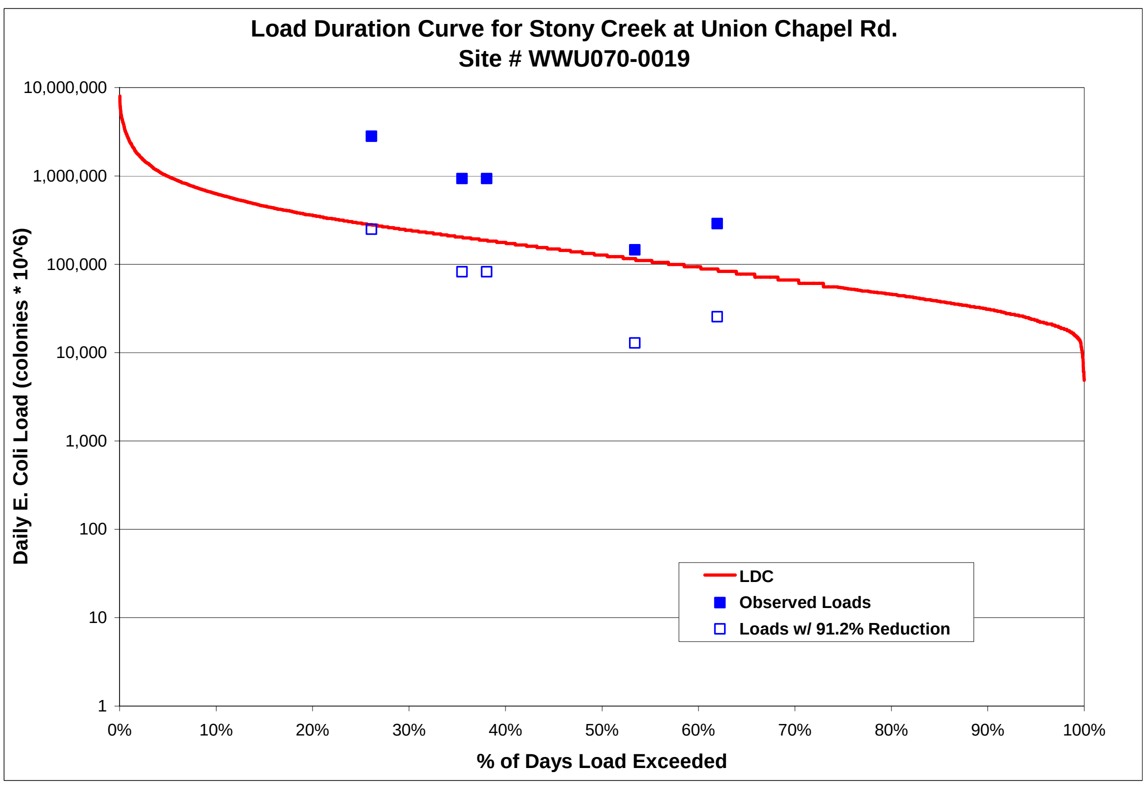
Load Duration Curve for Stony Creek at E 196th St.
Site # WWU070-0024
Daily E. Coli Load (colonies * 10^6)
10,000,000
1,000,000
100,000
10,000
1,000
100
10
1
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
% of Days Load Exceeded
LDC
Observed Loads
Loads w/ 89.4% Reduction


Load Duration Curve for William Lehr Ditch at 166th Street
Site # WWU070-0020
Daily E. Coli Load (colonies * 10^6)
1,000,000
100,000
10,000
1,000
100
10
1
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
% of Days Load Exceeded
LDC
Observed Loads
Loads w/ 89.4% Reduction

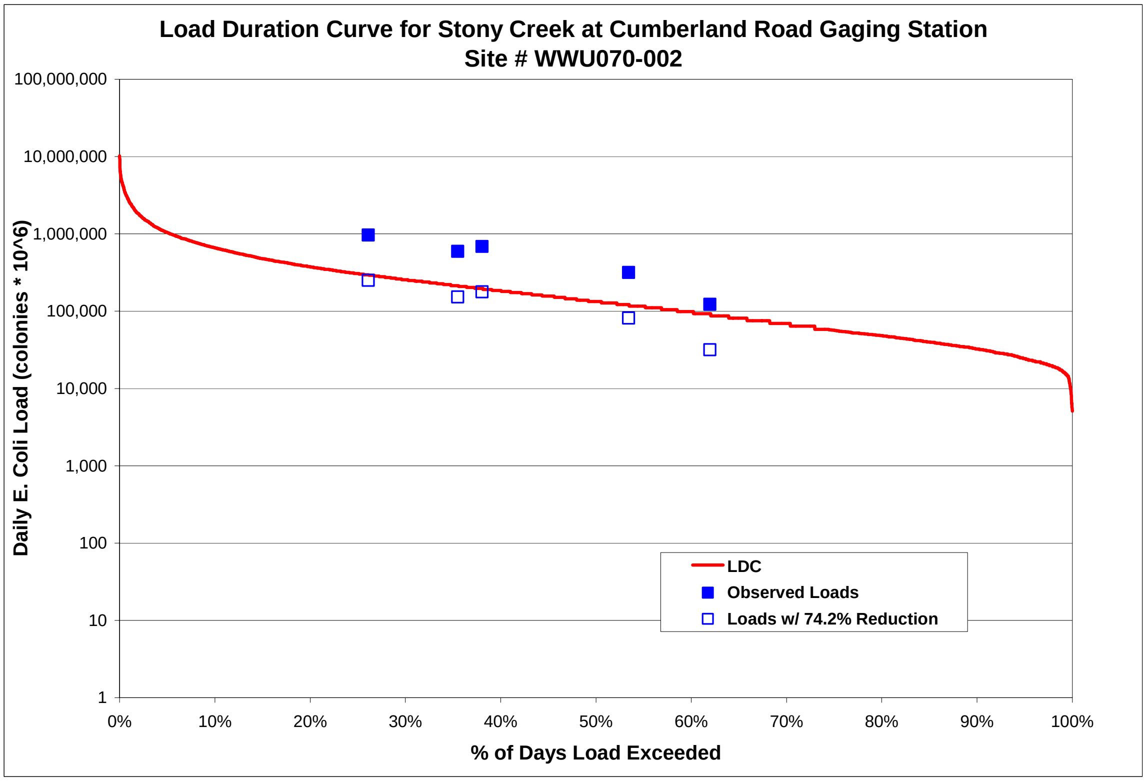

Load Duration Curve for William Lehr Ditch at Private Drive off SR 38
Site # WWU070-0021
Daily E. Coli Load (colonies * 10^6)
10,000,000
1,000,000
100,000
10,000
1,000
100
10
1
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
% of Days Load Exceeded
LDC
Observed Loads
Loads w/ 89.4% Reduction



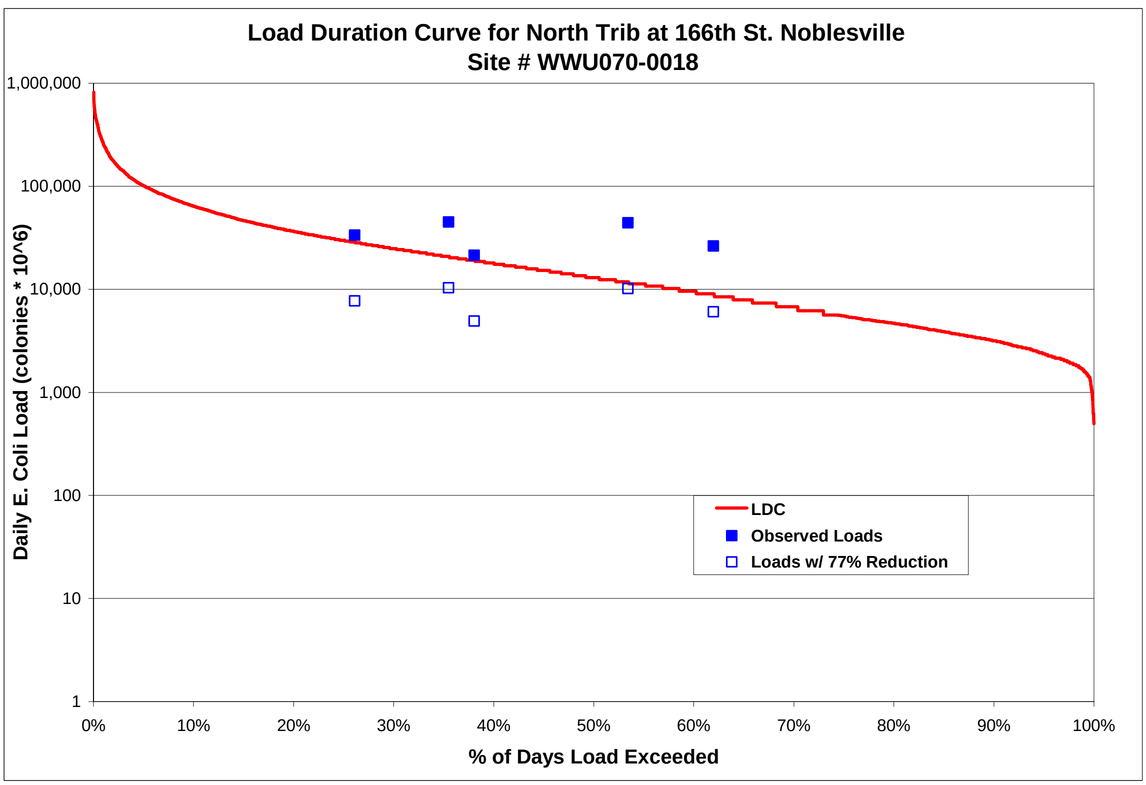
Load Duration Curve for Stony Creek at SR 38
Site # WWU070-0022
10,000,000
1,000,000
100,000
10,000
1,000
100
10
1
Daily E. Coli Load (colonies * 10^6)
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
% of Days Load Exceeded
LDC
Observed Loads
"Loads w/ 89.4% Reduction"



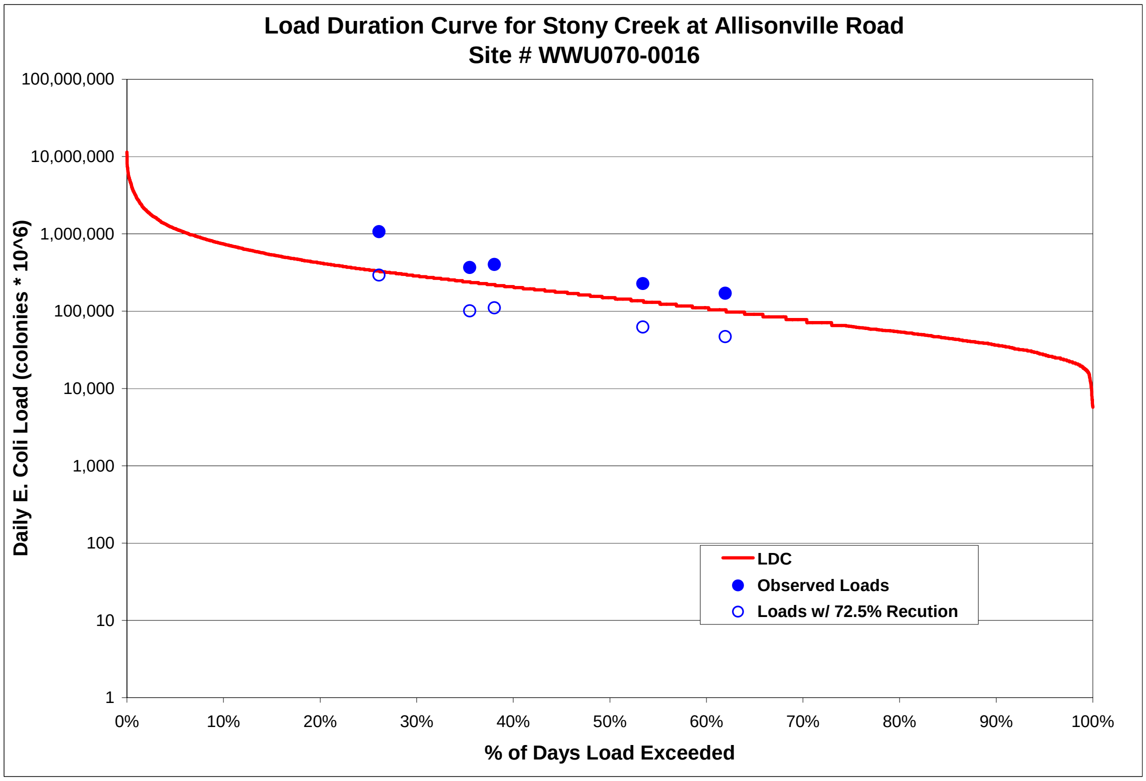
Load Duration Curve for Stony Creek at Union Chapel Rd.
Site # WWU070-0019
10,000,000
1,000,000
100,000
10,000
1,000
100
10
1
Daily E. Coli Load (colonies * 10^6)
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
% of Days Load Exceeded
LDC
Observed Loads
Loads w/ 91.2% Reduction



Load Duration Curve for Stony Creek at Cumberland Road Gaging Station
Site # WWU070-002
Daily E. Coli Load (colonies * 10^6)
100,000,000
10,000,000
1,000,000
100,000
10,000
1,000
100
10
1
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
% of Days Load Exceeded
LDC
Observed Loads
Loads w/ 74.2% Reduction



Load Duration Curve for North Trib at 166th St. Noblesville
Site # WWU070-0018
Daily E. Coli Load (colonies * 10^6)
1,000,000
100,000
10,000
1,000
100
10
1
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
% of Days Load Exceeded
LDC
Observed Loads
Loads w/ 77% Reduction



Load Duration Curve for Stony Creek at Allisonville Road
Site # WWU070-0016
100,000,000
10,000,000
1,000,000
100,000
10,000
1,000
100
10
1
Daily E. Coli Load (colonies * 10^6)
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
% of Days Load Exceeded
LDC
Observed Loads
Loads w/ 72.5% Recution